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Special Australian Herpetological Society 50th Anniversary Conference Issue.

An Australian Reptile Club meeting in the early 1950's

Photo: courtesy Roy Mackay. Thanks to Roy & David McPhee for identifications.

Back Row L to R: Margaret Mackay, David McPhee, Anthony Graham, Laurie Greenup, Alan Willows, Ray Witchard, Hans Verboorg, Roy Mackay.

Front Row L to R: Fred Fricke, ?, Sophia Verboorg, Mrs Alex Holmes, Margaret Leiper, Alex "Rusty" Holmes.

Herpetofauna is published twice yearly by the Australasian Affiliation of Herpetological Societies. The Affiliation started on an informal basis in 1974 and was formally established in 1977. It is the result of a formal agreement between member societies to participate in cooperative activities.

The Affiliation's objectives are to promote the scientific study of amphibians and reptiles and their conservation, to publish the journal *Herpetofauna*, to encourage liaison between societies at the regional level. It is not intended to be a separate society, nor is it to deplete member societies of their vital expertise and resources.

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AUSTRALIAN HERPETOLOGICAL SOCIETY

On the 2nd – 4th October 1999 the Australian Herpetological Society held a Conference on Captive Husbandry and Conservation of Reptiles and Amphibians to celebrate the 50th Anniversary of the Society.

This issue of herpetofauna comprises some of the papers presented at that Conference. It is appropriate to include here a brief history of the Australian Herpetological Society, prepared by Dr Glenn Shea, that appeared originally in the 50th Anniversary brochure.

The Australian Herpetological Society was founded, as the Australian Reptile Club, in 1949 and was the first natural history society in Australia devoted specifically to herpetology. In its early days the Society drew together such names as Roy Mackay, Bill Hosmer, John and Ken Dwyer, Henry Hirschorn, Rusty Holmes, Wal Lorking and Kevin Budden (the latter was to soon die from a Taipan bite when collecting specimens for an attempt to develop an antivenene.) A very young Harold Cogger was a junior member and Eric Worrell was closely associated with many of the early activities. David McPhee also became a member in the early decades.

At the time of the Society's formation, the only identification guide for any Australian reptiles was the 1929 "Snakes of Australia" by Kinghorn, long out of print and published knowledge of the ecology and husbandry of Australian reptiles and amphibians was almost non-existent. Within a few years of its formation, with members involved in fieldwork in what were then (and in some cases still are) extremely remote parts of Australia the Society began its first newsletter, The Australian Reptile Club Journal. This was soon followed by a more formal publication, Reptilia, to report members observations. Both of these were short lived. However in 1963 a new publication, Herpetofauna was initiated, the title reflecting the broader range of interests and change in name of the Society. The first issue of the new publication carried a warning from the then Secretary, David Millar that all members of the Society were expected to contribute one article per year for the fledgling magazine. It took seven years for another issue to come out! However once Herpetofauna reappeared it has never looked back and is now the major amateur herpetological journal in Australia with a readership of both professionals and amateurs.

With the broadening of the membership base to other Australian states, a Victorian branch of the Australian Herpetological Society was established in 1972, becoming independent in 1976 as the Victorian Herpetological Society. In 1975 the Herpetological Section of the Royal Zoological Society of New South Wales was amalgamated with the Australian Herpetological Society and in 1976, the future of Herpetofauna was more firmly established with the formation of the Australasian Affiliation of Herpetological Societies, of which the Australian Herpetological Society was a founding member. More recently the Frog and Tadpole Study Group of NSW was initiated as a special interest group of the Society, becoming independent in 1994.

The Australian Herpetological Society was closely involved in the formation of the Reptile Keepers Association in 1984 and together with that organisation initiated discussions on reptile and amphibian licensing with the New South Wales National Parks and Wildlife Service. After a long and often frustrating twelve years of meetings, which had to cope with changes of government, new directors and restructuring of the Service, a new licensing system was established in New South Wales in 1997. This new system has opened up herpetoculture in this state, allowing interested keepers to legally acquire and transfer stock and disseminate information on husbandry and breeding without fear of prosecution.

AUSTRALIAN HERPETOLOGICAL SOCIETY CONFERENCE

A talk given by Roy Mackay, first president of the Australian Reptile Club (the forerunner of the AHS), at the 50th Anniversary Conference dinner.

I find it astounding that the small group of us who met at my place in Newtown, Sydney in April, 1949 and initiated the Australian Reptile Club would be the forerunners of what is now a very important society with members and influence in all States.

Members range from the eager and over-eager collector to the serious scientist. And to see the beautifully produced journal, Herpetofauna, is proof that the Society is thriving. What more proof is needed that the Society is in a healthy state than to see this Conference. It is no mean feat to organize such an event.

There are times when groups of reptile collectors or enthusiasts are considered to be a mad bunch of ratbags, myself among them. Maybe we were but now you see what a bunch of ratbags started.

Of course, there may always be the element which considers that having the largest collection is more important than finding out a new and important fact about the life of one reptile but fortunately over the years the study of reptiles and amphibians has become very serious and new and wonderful facts are emerging from the laboratories of museums and universities every year.

The other day I looked out my copies of the early journal of the Australian Reptile Club which we called Reptilia. They helped me to remember many of our early members - Alex Holmes, Wal Lorking, George Longley, Hal Cogger, John and Ken Dwyer, Bill Irvine, my wife, Margaret, Shirley Collins, Henry Hirschhorn, Bill Hosmer, John Corcoran, David McPhee, Kevin Budden, Ken Smith and many more.

We had some memorable trips, made some marvellous catches and generally had a wonderful time.

A funny thing happened on the way out west near the Macquarie Marshes. Talk about adventures in reptile collecting. My wife and I, and Hal Cogger went collecting near Quambone near the Macquarie Marshes one time. We were going along a stream. I was on a high bank and looked across to Margaret and Hal walking along the other side which was low and covered with scrub. Just as they came around a bend in the stream a wild boar broke its cover. Hal took off and did the hundred metres in two seconds flat. Then he stopped, suddenly turned around and said, "Oh! Oh! Margaret are you alright?" Then, of course, they realized that the boar had got just as big a fright and had gone in the opposite direction.

Then there was Bill Irvine who was a very fearless and diligent collector - afraid of nothing. It came about that we found his Achilles heel. He was collecting on a steep slope which went down in 20 metre steps where small bushes and many rocks suitable for reptiles to hide under were distributed around. He walked between two of the bushes, right into an Orb-Weaver Spider. By reflex action Bill threw himself aside and tumbled down the slope, luckily not doing permanent damage but certainly bruised and scratched.

It has been said that the owners of pets often come to look like their pets. We had a wonderful old gentleman in the early days named George Longley. He specialized in keeping Blue-tongued lizards and there was no one more expert in keeping and breeding them. In fact, if you were to read his notes published in the Proceedings of the Royal Zoological Society of NSW (late 40s) today I'm sure you could pick up some ideas. After a few years of keeping them you could notice that while he was talking to you he would frequently put his tongue out - like a blue-tongue lizard.

What does the future hold? One thing is certain - further destruction of habitat. Another thing is certain - greater population, including more collectors. However, at the same time, there probably will be more revealing studies on reptiles, more taxonomic changes, more DNA studies, more natural history and biology on reptiles and amphibians. I suggest that this Society could become greater and more important especially if it can help other organizations to try to markedly slow down the destruction of habitat.

I wish you all and the Society a grand future.

THE DEVELOPMENT OF AUSTRALIAN HERPETOLOGY - SOME STATISTICS

Hal Cogger

INTRODUCTION

In the course of preparing statistical information on the history of Australian herpetology for a variety of presentations and publications, I constructed a small number of graphs that summarise aspects of the development of Australian herpetology. These aspects included the growth of an Australian herpetological literature and the chronological pattern of the establishment of the named taxa - with particular emphasis on species - of Australian reptiles and amphibians.

These graphs, which with one part exception (Cogger, 1993) have not previously been published, are derived primarily from a taxonomic database that originally was developed as a precursor to a taxonomic catalogue of the Australian herpetofauna (Cogger *et al*, 1983). Developed concurrently was a bibliographic database of works on, or of direct relevance to, the Australian herpetofauna.

Since publication of the catalogue, both databases have been kept as up-to-date as possible, although the bibliographic references are inevitably incomplete, especially in regard to more recent publications. This is because there is often a lag time between publication and scanning by citation journals, especially of articles in low circulation or more obscure journals, magazines and newsletters.

The original purpose in preparing these graphs was to illustrate the differences in the history of the development of scientific knowledge of the Australian herpetafauna when compared with the herpetological histories of other major regions. Such differences reflect Australia's late colonisation, social changes from its origin as a penal colony to its current status as an outlier of western culture and science, its long geographic isolation and the consequent high endemicity of its fauna, and the history of exploration and development of areas remote from its centres of population.

Because the information comes from two distinct but overlapping sources - formally named taxa and publications on all areas of herpetology - two different but correlated patterns emerge. Whereas bursts of taxonomic descriptive activity shown in the graphs may result largely from the work of one or a few individuals, variation in the number of general publications in herpetology tend to reflect input by many individuals. Nevertheless, both data sets tend to reflect the same broad patterns over time.

Two distinct sets of *taxonomic* information are contained in these graphs: newly-described taxa (each represented by an "available" name) and valid taxa (i.e. those currently recognised as valid by a majority of herpetologists and that consequently have a valid available name attached to them).

The history of Australian herpetology has been documented briefly, or in part, in a number of publications (Whitley, 1970,1975; Shea, 1995; Main, 1993; Cogger, 1985,1993). While special attention has been given to the growth of taxonomic knowledge of the Australian herpetofauna, less attention has been paid to other fields of herpetological research.

In order to explain the variations displayed in these graphs it is important to have some understanding of the historical and social changes that have occurred in Australia and elsewhere and that have driven or influenced the collection and study of Australia's herpetofauna. Cogger (1993) identified several key, though arbitrary and often overlapping, phases in the development of Australian herpetological knowledge, both taxonomic and biological:

Pre-settlement (pre-1788) - during this phase the first knowedge was gleaned of nonendemic Australian taxa which were widespread beyond Australia (e.g. sea turtles, crocodiles) or of endemic taxa noted by mariners on brief shore excursions on Australia's northern and western coasts.

First settlement (1788 - *ca.* 1830) - this phase was characterised by a natural curiosity to identify a totally new fauna, albeit with a preoccupation with those elements that might be life-threatening or edible or that might have medicinal or commercial value. It included the first explorations of many coastal parts of Australia.

Early continental exploration (*ca.* 1820 - 1850) - descriptions, drawings and sometimes specimens of newly-encountered species as part of documenting the natural products of the new environments encountered. In general, frogs and reptiles were of little interest compared with plants and higher vertebrates which were likely to be important to future settlers.

Collection-building (*ca.* 1830 - 1880) - as the colonies became more self-sufficient, social and economic independence gave rise to formal educational and scientific structures such as universities and museums. Initially collections were made only to display natural curiosities to the local community or for shipment to Europe for research and display. Research collections were only gradually built up and maintained in Australian institutions.

The European cataloguers (*ca.* 1820 - 1890) - the flourishing and expanding empires of Europe, with their newly-acquired lands and their diverse biotas, combined with the expanding role of science accompanying the industrial revolution, led to the establishment of large public institutions to house, describe and catalogue the natural products of their new possessions. Like today's taxonomists, rivalry to be the first to describe new taxa was sometimes intense and bitter. And, as now, Australian zoologists often had to consult collections in Europe in order to confidently identify specimens at home.

Australian-based herpetology (*ca.* 1850 - 1900) - It was not really until the 1860s, with the appointment of the young German Gerard Krefft as Curator (i.e. Director) of the Australian Museum in Sydney that indigenous herpetology took off. Krefft built the first scientific (as against display) collections, undertook field work specifically to study frogs, reptiles and other native fauna, and published many scientific papers and books. He fought the established colonial establishment and lost (Whitley, 1961), but his life and work illuminate this period in Australian herpetology. Krefft was swiftly followed by a growing coterie of zoologists resident in Australia. Most were museum-based, so that their research tended to be largely taxonomic, but individuals within the State universities gradually built up knowledge of the natural history of many species that were geographically accessible.

The Great Wars (1914 - 1945) - this period had a profound and depressing influence on Australian herpetology. Australia was just climbing out of an extended recession when World War 1 commenced, and during which scientific staffs had been reduced in major institutions. After the war, a brief resurgence was soon brought to a halt by another economic depression and the build-up to World War 11. This pattern is dearly reflected in the slope of the curves for this period in figures 2 and 8.

Post-World War 11 (1946 - 1999) - This period has been characterised by unprecedented growth in Australian herpetology, in part because of increased opportunities for training and research, in part because of the opening up of much of remote northern Australia for agriculture, mining, national parks and aboriginal homelands, and also because of an increasing preoccupation with environmental and conservation issues in a post-industrial, high-consumption society in which loss of biodiversity is of growing concern. Moreover, the growth of biochemistry and molecular biology has revitalised taxonomic

research because of its ability to define, rather than infer, the degree of genetic relationship between organisms.One or more of these phases is clearly reflected in the patterns displayed in the figures below.

The Graphs

As indicated above, the sources of the data presented below are bibliographic and taxonomic databases developed, in part, by the author and his colleagues at the Australian Museum, and which have been published in part (Cogger et al., 1983).

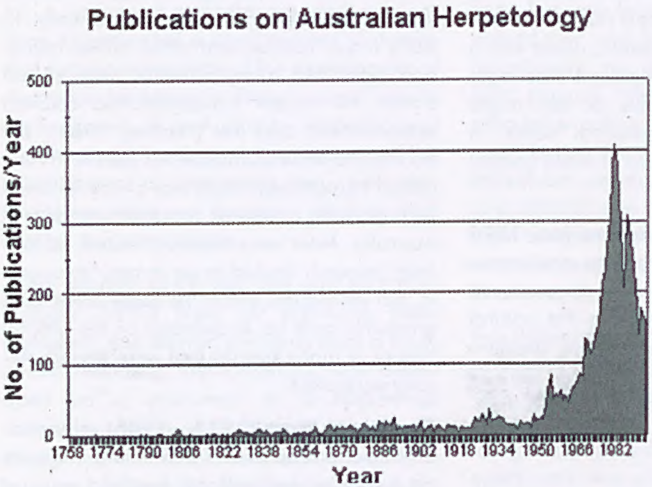

Figure 1

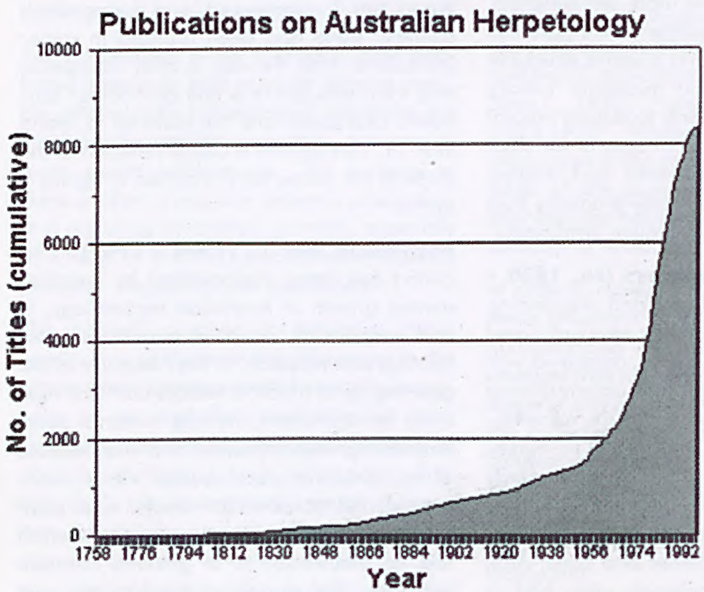

Figure 2

Figures 1 and 2 , based on the same data set, illustrate the growth of the literature on Australian herpetology, as measured by number of publications per year (figure 1) and the cumulative number of papers published each year (figure 2). Two points are worthy of note. First, despite the richness of Australia's herpetofauna, an indigenous literature was slow to start and remained at a low level for more than a century. An annual total of 10 titles was first attained in 1827, and did not reach 20 until 1890 and 50 until 1953. Second, more titles have appeared in the past 25 years than in the preceding 190, reflecting the great renaissance in Australian herpetology following the second World War.

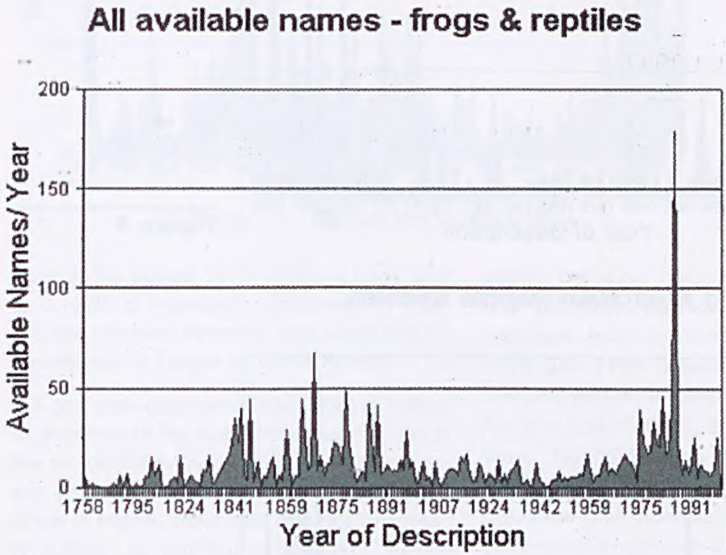

Figure 3

Figure 3 graphs, by year, the number of newly-proposed species-level taxa (most as represented by available names) of Australian amphibians and reptiles. It is based on some 2250 names applied to the approximately 1050 valid species-level taxa currently recognised as occurring in Australia and its territories and territorial waters (Cogger, 2000). Note that, as might be expected, the patterns of descriptive activity closely reflect those for valid species-level taxa in figures 4 (amphibians) and 5 (reptiles). One major exception to this pattern is discussed below.

Figures 4 and 5 illustrate, respectively, the numbers of currently recognised Australian frog and reptile species described each year since the start of the Linnean system of classification in 1758. The patterns shown for both groups are similar, and reflect the wide fluctuations in descriptive taxonomic activity already alluded to in the introduction. Although one might expect non-taxonomic herpetological researches to lag behind the taxonomic studies that underpin them, this does not appear to be the case. Reflecting to a lesser extent the pattern for herpetological titles in figure 1, the known herpetological fauna of Australia has virtually doubled in the past 50 years

In figures 6 and 7 I have provided two additional analyses which clearly reflect the phases cited in the Introduction above, including Australia's exploration history and growing indigenous scientific research base. The first (figure 5) compares the growth of knowledge of the taxonomy of the Australian herpetofauna with that of other major regions by superimposing on figure 5 the record of the description of the currently recognised (i.e. valid) species of reptiles of Europe and North

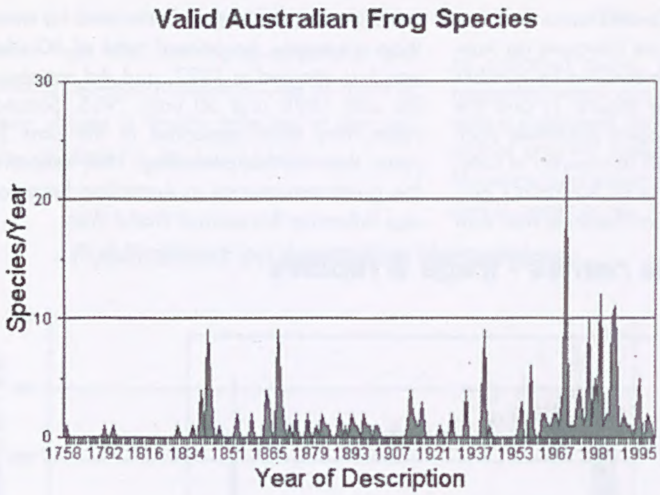

Figure 4

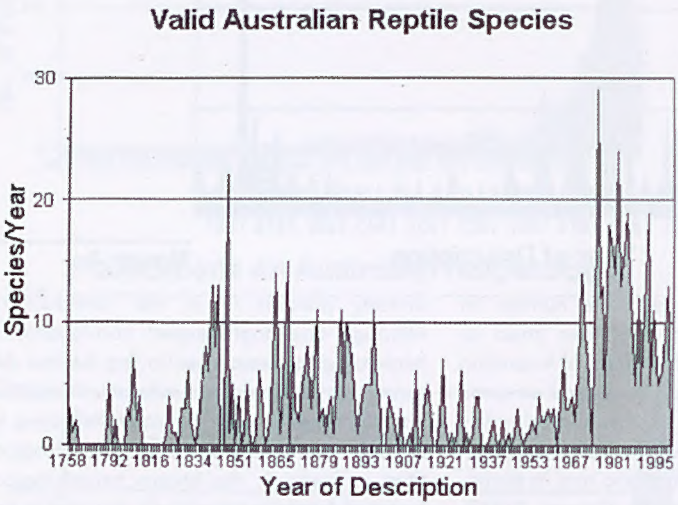

Figure 5

America. For the purposes of the analysis, valid species are those recognised by Cogger (2000) from Australia, by Arnold and Burton (1985) from Britain and Europe, and by Behler and King (1988) from North America.

As might be expected, the great bulk of European species had been formally described before the end of the 19th century. North American and Australian species, on the other hand, though both having major descriptive phases coinciding with that of the European cataloguers referred to above, also had additional descriptive phases extending well beyond that of Europe. While most North American species had been described by the end of the l9th century, new taxa continued to be described in small numbers throughout the 20th century.

In Australia, too, the end of the 19th century marked the end of a great descriptive phase which continued, albeit at a reduced level, until the first World War intervened. Not until the 1950s is there a resurgence in descriptive activity which appears to have reached a

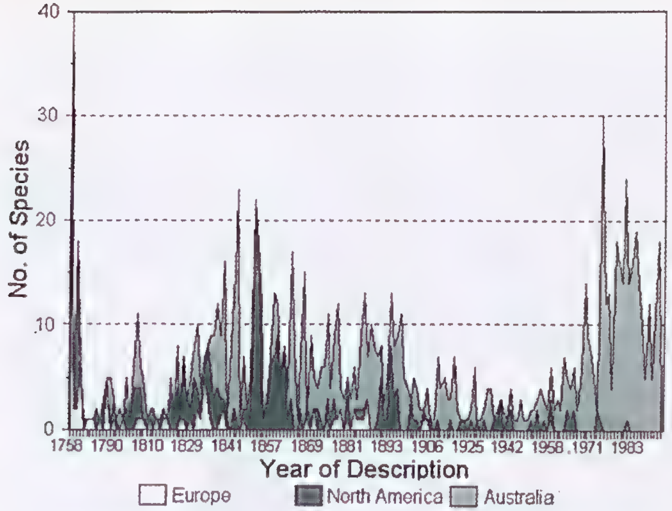

Figure 6

peak in the period 1970-1990, in large part as a result of increased field surveys in western and northern Australia. This phase has no counterpart in Europe or North America.

But one phenomenon of the ongoing history of discovery of the Australian herpetafauna is the recent discovery of highly distinctive genera and species even from long-established areas of human settlement or areas previously subject to significant biological survey. Examples of such species include the southern gastric brooding frog (*Rheobatrachus silus*) and day frog (*Taudactylus diurnus*), both described from an area near Brisbane in 1973 and 1966 respectively, the very large Oenpelli python (*Morelia oenpelliensis*) from Arnhem Land (1977), the monotypic scincid lizard *Nangura spinosa* from mid-eastern Queensland (1993) and, most recently, the distinctive and monotypic myobatrachid frog *Spicospina flammocaerulea* from south-western Australia (1997).

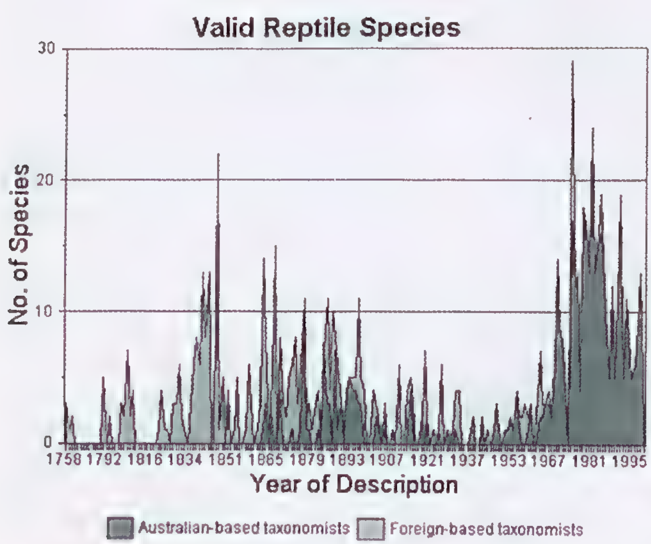

Figure 7

In figure 7 distinction is made between those valid Australian species of reptiles described by herpetologists residing outside Australia and those described by workers based in Australia. The pattern displayed clearly indicates the commencement of an indigenous Australian taxonomic herpetology in the mid-19th century, and its fluctuating productivity until the great burst of descriptive activity which has characterised the latter half of the 20th century.

Finally, the data utilised to produce figures 4 and 5 have been combined to produce figure 8, a graph which shows the cumulative numbers of valid species of Australian amphibians and reptiles from 1758 to the present.

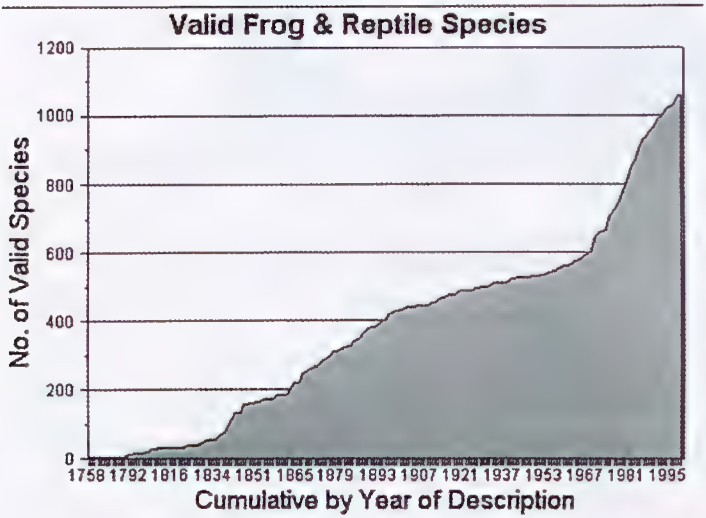

Figure 8

General Remarks

Most of the data presented in figs 1-7 are readily available from the literature, but are widely dispersed. It is hoped that their presentation here in such a condensed form will encourage the analysis of future patterns in the development of Australian herpetology.

Because it has elicited questions and comments when these graphs have been presented to different audiences, the sharp peak shown as occurring in the mid-1980s in figure 3 warrants further comment, especially for those unfamiliar with the recent history of Australian taxonomic herpetdogy.

In two publications in particular, Wells and Wellington (1994, 1995) formally described some 255 new taxa, potentially increasing the number of then-recognised valid genera from 149 to 237, and the number of then-recognised valid species from 830 to 997.

The large number of taxa proposed by Wells and Wellington (athough many proved to be *nomina nuda*), the poor quality of some of their descriptions and diagnoses, their preparedness to describe taxa or nominate types based on specimens that they had never seen, and to describe taxa which other herpetologists had previously indicated were in the process of being described, caused a furore in Australian herpetology. An application was subsequently made by the Australian Society of Herpetologists for three of the Wells and Wellington works (including the two cited above) to be suppressed.

While the case was under consideration between June 1987 and December 1991, the provisions of Article 80 of the third edition of the Code then in effect required the maintenance of "existing usage". While the exact interpretation of the "existing usage" clause in such a case was ambiguous, some herpetologists proceeded with describing and publishing the names of new taxa that they had been working on prior to the Wells & Wellington publications, and to which some of the Wells and Wellington names might well apply. Indeed, some workers were required to propose new names by editorial decree. In many cases this resulted in two different names being proposed for the same taxon. Some herpetologists, myself included, had used some of the Wells and Wellington names *prior to* the submission of the ASH application, and therefore prior to the application of the "existing usage" provisions of the Code, resulting in a "dual nomenclature", some of which continues to exist.

After a lengthy period in which the views of the world's zoologists were sought on the application, the Commission ruled that the case was essentially taxonomic rather than nomenclatural, taking it outside the Commission's remit. This meant, in effect, that the Commission would only rule on the priority of one of two or more competing names when formally requested to do so, and that its decision would be guided by its overarching objective of promoting "...stability and universality in the scientific names of animals and to ensure that the name of each taxon is unique and distinct". Consequently future "usage" (by zoologists) of the Wells and Wellington names will be the primary consideration in determining whether the Commission is likely to set aside the chronological priority provisions of the Code if requested to do so.

In making its ruling on the Australian Society of Herpetologists' request for suppression of the Wells and Wellington works, the Commission stated, *inter alia*, "...that, by departing from the voluntary Code of Ethics in the International Code of Zoological Nomenclature, Wells and Wellington have displayed a contempt for the Code and its arbitration provisions" and that "the Commission deplores the clear rejection by Wells and Wellington of virtually every tenet of the voluntary Code of Ethics which forms Appendix A of the Code."

One further qualifying comment relating to the data presented in the graphs above is that there has been a tendency to regard the number of taxa described in any given period as a rough measure of the level of herpetological research during that same period. However, figures 2 and 8 demonstrate clearly the poor correlation between number of taxa described and the level of herpetological research (as reflected in the number of publications in herpetology).

In summary, Australia has been shown in recent years to possess a much richer herpetofauna than expected from earlier studies. It possesses many recently-discovered taxa that are biologically and morphologically bizarre, some from areas near long-established population centres or from areas that have been extensively surveyed. The survival of many of these recent discoveries is already threatened, while some (such as the southern gastric brooding frog and the day frog) are already believed to be extinct. The loss of such species, first described only in 1973 and 1966 respectively, typifies the problem facing Australia and many other countries in our region, where there is a high probability that unique endemic but currently undescribed taxa will disappear before we are even aware of their existence.

ACKNOWLEDGMENTS

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CAPTIVE MAINTENANCE AND BREEDING OF AUSTRALIAN LEAF-TAILED GECKOS *(SALTUARIUS AND PHYLLURUS)*

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INTRODUCTION

Taxonomic reviews of the Australian leaf-tailed geckos have recently described a new genus and several new species (Couper *et al*, 1993; Couper *et al*, 1995). Currently the number of recognised species stands at ten; five each in the genera *Saltuarius* and *Phyllurus*. It is likely that additional species will be described over the next few years (P. Couper pers. comm).

All species are restricted to the eastern seaboard of Australia, from the Sydney Basin in the south *(P. platurus)*, to the McIlwraith Range, Queensland in the north *(S. occultus)*. All species occur within 300km of the coast and occupy a range of habitats from rock escarpments to woodland and rainforest (Porter, 1997 a, b). Most species are at least semi-arboreal. Even the saxicolous species such as *P. platurus* and *S. wyberba* will occasionally spend some time foraging on tree trunks and shrubs adjacent to rock outcrops. Nocturnal activity periods are the norm, and all appear to be generalised opportunistic insectivores (Wilson & Knowles, 1988).

HUSBANDRY

Eight species have been maintained in captivity to date and all have proved to be hardy and adapt quickly to captive conditions. These include *Phyllurus caudiannulatus, P. ossa, P. nepthys, P. platurus, Saltuarius cornutus, S. salebrosus,* (Figure 1) *S. swaini* and *S. wyberba.*

Suitable housing can be very basic. Enclosure sizes can be quite small as leaf-tails are relatively inactive lizards and thus do not need large amounts of space (Figure 2). For example, a pair of the largest *Saltuarius* species can be comfortably housed in an enclosure measuring 50 x 30 x 70cm high. Smaller species such as *P. caudiannulatus* can be maintained as a pair or trio in an enclosure size of 45 x 25 x 35cm high. Timber, glass and perspex are all suitable materials, although if the former is used it needs to be sealed as high humidity levels are required. It is also essential that plenty of ventilation is supplied in any enclosure. Installing mesh covered vents at the top and bottom of the cage permits efficient air flow; the warmer air leaving at the top drawing in cool, fresh air at the bottom. This is particularly important with species needing humid environments, as stale, moist conditions will quickly lead to a proliferation of potentially dangerous pathogens. All mesh must be metal as any feed insects not consumed by the geckos will eat through the nylon product.

Cage furniture needs to be of a type and placement such that the animals can use the full dimensions of the enclosure. Rigid strips of ironbark bark placed vertically and arranged in layers are ideal. These provide narrow crevices for the lizards to hide in during the day and a rough surface allowing a comfortable grip when active. Additional tree branches can also be installed to allow extra climbing space. Rocks may be used, however, rock piles or layers can be very dangerous if they are unstable or if accidentally dropped when checking lizards. Rock-inhabiting species appear to be quite content using tree bark in captive situations. Suitable substrates include potting mix, palm peat or fine washed beach sand. The latter has been used exten-

sively without incident, although others have reported problems with gut impactions in leaf-tail species (P. O'Callaghan pers. comm.) The advantages of using sand are that it is cheap, readily available and easy to keep clean and, provided the lizards have plenty of climbing furniture where they can forage without ingesting large amounts of substrate, it does not appear to be a health hazard.

All leaf-tailed geckos are cool-adapted species so high temperatures are not required. Each cage has an incandescent light fitting with coloured bulbs of 25-60 watt, depending on the species and season. The red or blue coloured bulb is kept on 24 hours a day during the breeding season without affecting the photoperiod. During early spring and late autumn the coloured bulbs may be replaced with a white light as heat is only provided during the day. No heat is provided over winter. Such a set-up will offer hot spots of no greater than 28-30°C. These geckos rarely actively thermoregulate. On only one occasion was an animal observed adjacent to the heat source evidently absorbing heat. Interestingly, this lizard, a juvenile *S. salebrosus*, oriented its tail towards the source using it as a heat absorption panel. General temperature gradients of 22-28°C in summer, down to 14-24°C in winter suit most species, with the temperate species requiring lower winter temperatures, as low at 6-8°C for *S. wyberba*, to ensure successful breeding.

A photoperiod approximately equivalent to the NSW Central Coast is provided, utilising light from adjacent windows or from fluorescent tubes above each cage. Artificial ultraviolet light is supplied to some cages but it does not appear to be an essential requirement to long-term health. Lizards have never been observed basking during the day in captivity.

Humidity is a critical environmental attribute that needs to be carefully monitored for most species. Rainforest species (e.g. *S. cornutus, S. swaini, P. caudiannulatus*) in particular need a consistently high relative humidity around 70-90%, a level that can be achieved with regular spraying of enclosures. Other species require humidity levels between 50 - 80%. Close attention to skin sloughing of the animals concerned will immediately highlight humidity problems as pieces of retained skin will remain attached around feet, digits and eye sockets if these levels are too low.

Leaf-tails are undemanding in their food requirements. Crickets, grasshoppers, cockroaches and mealworms are all eagerly accepted. Field research on *P. platurus* suggests a small number of large prey are consumed, rather than many small items (Dougherty & Shine, 1995) and their powerful jaws enable them to handle sizeable insects quite easily. Meals of 2-3 crickets per lizard are offered 2-3 times per week between spring and autumn, reduced to one cricket every 7-10 days in winter. Once settled in captivity, all species will readily feed from forceps. Food items are dusted with a calcium/multivitamin powder once or twice per week during the breeding season, but only once per month in winter.

REPRODUCTION

Sexing leaf-tails is straightforward. Males possess distinct swellings at the base of the tail and are always much less robust than the females. Males also appear to be more nervous, highly strung lizards than the calmer females. All species can be housed as pairs or trios of one male and two females all year round. Some success has been achieved with housing multiple males together in some species, e.g. *S. swaini*, even in the presence of a female. However, in many cases male geckos can be extremely aggressive towards each other and care needs to be taken if such a set up is to be used.

In captivity, eggs are laid from mid-September through to mid-January with up to three or four clutches produced each season. With *S. swaini* at least, the female can continue to produce fertile clutches for up to seven months after a mating (K. Aland pers. corn.). Developing eggs are visible in the abdomen of females as cream- coloured evenly rounded objects. Some females develop large, fat

bodies at certain times of the year and these may be confused with developing eggs; however, the former tend to have a more asymmetric outline and positioning.

For oviposition, a plastic container of permanently moist palm peat mixed with a little beach sand is installed on the enclosure floor. This provides not only somewhere for the female to lay, but it also assists with maintaining the humidity in the cage. Substrate to a depth of 8-10cm is required and the container should be at least slightly longer than the length of the lizard concerned. Females of most species will excavate to the bottom of the substrate, deposit the eggs and cover them over (Figure 3). The substrate will usually be left mounded up over the oviposition site permitting easy retrieval of eggs.

Eggs can be successfully incubated in a 1:1 ratio of vermiculite to water by weight. Appropriate temperatures for most species range between 22-26°C, though species such as *S. salebrosus* will hatch at temperatures one or two degrees higher. Some difficulties have been experienced with incubation of *S. swaini* eggs mainly in the form of embryos dying close to full term (K. Aland pers. comm.; pers. obs). At this stage no reasons for these deaths are evident. Experimentation with incubation temperature and humidity have not indicated any obvious patterns. Incubation times range from 60-100 days at the temperatures listed above (see Appendix 1).

Neonates are raised in round clear plastic containers around 25cm high and 15cm diameter containing a fine sand substrate and several strips of tree bark similar to the adult enclosure. Approximately one third of the bottom of the container is positioned over a heat strip providing a temperature of 28°C on the substrate at this point, though juveniles have never been observed utilising his hot spot for thermoregulation. The enclosure is sprayed with water daily, allowing the run-off to soak the substrate on one side of the container. Food, in the form of 3-4 juvenile crickets per lizard, is offered every second day and dusted with a calcium/multivitamin powder twice per week. The feeding frequency is reduced in winter to 1-2 feeds per week depending on the prevailing ambient temperature. Growth is relatively slow compared to other Australian gecko species, with maturity achieved in around three years for most species (*P. caudiannulatus, P. platurus, S. salebrosus* and *S. swaini* pers. obs). Sexes can be differentiated at 8-14 months of age.

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Appendix 1. Egg size at laying and incubation times and temperatures recorded for geckos in the genus *Phyllurus* and *Saltuarius*.

SPECIES	EGG SIZE AT OVIPOSITION(mm)	EGG MASS AT OVIPOSITION (g)	INCUBATION TIME(days)	TEMP °C	SOURCE
P. caudiannulatus	17.4-21.6x9-13.5 (n=27)	1.1-1.86 (n = 6)	60-85	23-27	pers. obs.
P. platurus	-	-	64	28	H. Seufer, pers. comm.
	18.6 - 25.5 x 9 - 14.4	-	-	25	Dougherty & Shine,1995
	20.92-25.03 x 15.28-15.85	-	71 - 72	-	Couper *et al*, 1993
	23.5 x 12.4 (n = 4)	1.59-2.5 (n = 4)	66	22 - 26	pers. obs
	-	-	85-98	20-25.	Henkel & Schmidt, 1995
S. cornutus	28 x 18	-	-	-	Anthony, 1993
	-	-	49 - 63	26 - 32	M. Cermak, pers. comm.
	26.62 x 16.05}	-	100	24	Couper *et al*, 1993
	27.24 x 16.44}				
	23.3-25.7 x 13.6-15(n = 16)	2.57 - 3.18 (n=10)	66-76	24-27	pers. obs
S. salebrosus	27.7-29.5 x 16.5-17.5 (n = 16)	4.3 - 4.85 (n=6)	68	28-29.5	pers. obs.
		-	81-99	23-27	pers. obs.
S. swaini	22.4-26 x 12.7 - 15.5 (n=10)	2.23 - 2.77(n=6)	72 - 106	22-26	pers. obs.
S. wyberba	22.9-21.0 x 13.2-14 (n = 12)	1.95-2.0 (n = 4)	67 - 75	23 - 27	pers. obs.

Figure 1 Juvenile captive bred *S. salebrosus*

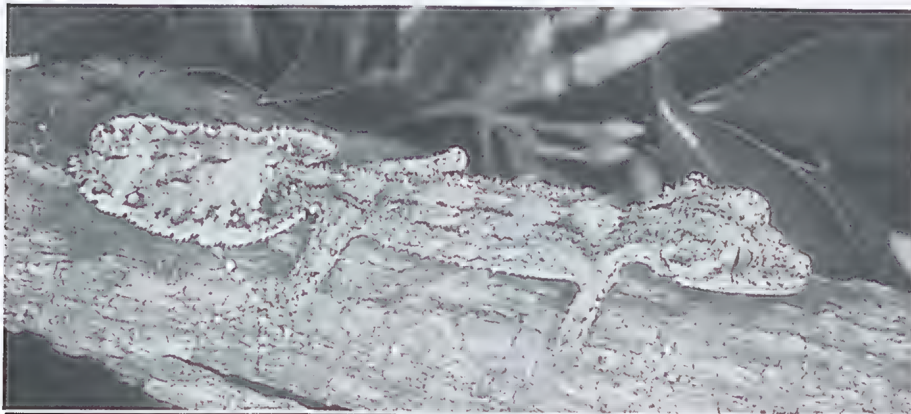


Figure 2 Caging for Leaf-tailed geckos

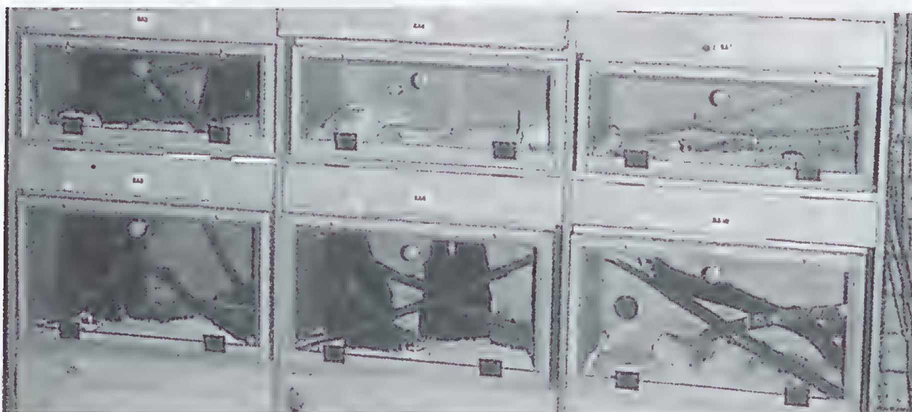
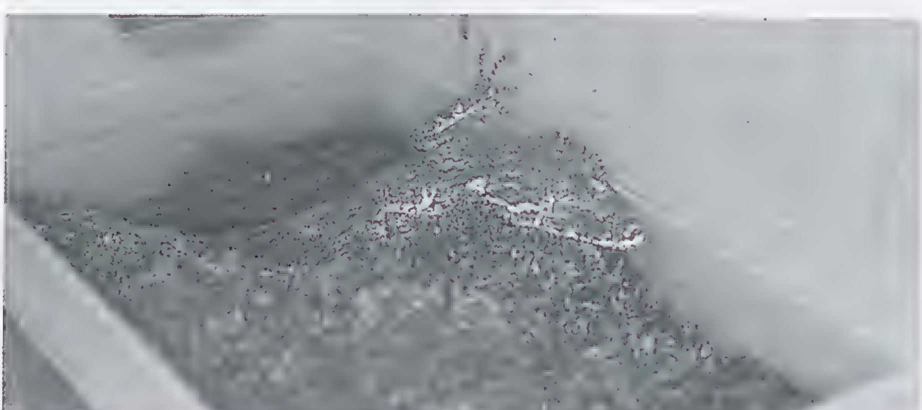


Figure 3 *S. cornutus* laying eggs



CAPTIVE MANAGEMENT AND BREEDING OF THE STRIPED LEGLESS LIZARD, *DELMA IMPAR*, AT MELBOURNE ZOO

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ABSTRACT

The Striped Legless Lizard, *Delma impar*, is confined to lowland native grasslands across south-east Australia. It is listed as Vulnerable at the national and global levels, and as Endangered in Victoria. Its management in Victoria is co-ordinated by the Victorian Striped Legless Lizard Working Group, which has representatives from the Department of Natural Resources & Environment, Melbourne Zoo, universities, non-government organisations, private landholders, community groups and ecological consultants. Melbourne Zoo is the site at which lizards salvaged from destroyed native grassland sites are lodged and has been holding specimens since 1991. This includes individuals still alive after seven years. Eggs from wild-mated females were hatched in 1992, but the first full captive breeding occurred in 1998. The eggs hatched after 42 days and the neonates averaged 0.7g and 40mm snout-vent length. As far as is known, this is the first captive breeding of this species. The techniques used to achieve this success are outlined, as are the broader captive management and public display protocols.

INTRODUCTION

The Striped Legless Lizard, *Delma impar*, is a member of the family Pygopodidae. It grows to an average snout-vent length of 90mm (Cogger, 1995) and an approximate total length of 300mm (Coulson, 1990). It is characterized by a series of dark brown or blackish dorso-lateral and lateral stripes running along the entire length of the body and tail (Cogger, 1995) (Fig. 1).

The species inhabits predominantly temperate lowland native grasslands in south-eastern Australia. This habitat type consists primarily of perennial tussock grasses, such as Kangaroo Grass, *Themeda triandra*, Speargrass, *Stipa spp*. and Wallaby Grass, *Danthonia spp*. Populations of *D.impar* are known to occur on the basalt plains of central, western and southern Victoria, northern ACT and around the neighbouring New South Wales centres of Batlow, Goulburn and Cooma (Cogger, 1995; Husband, 1995; Osborne *et al*., 1993; G. Husband, pers. comm.). *Delma impar* has also been recorded from the south-eastern corner of South Australia at Bool Lagoon, (Coulson, 1990; Hadden, 1995), but until very recently was thought to have disappeared from that area. However, specimens were recently found there by Department of Environment, Heritage & Aboriginal Affairs, SA, staff (Y. Ingeme, pers. comm.).

Since European settlement, native grasslands have contracted significantly and as a result become fragmented (McDougall & Kirkpatrick, 1994). The continuation of threatening factors, such as clearing for urban development and current agricultural practices, severely impinge on the survival of the Striped Legless Lizard. It is classified as Vulnerable internationally (IUCN, 1996), nationally (ANZECC, 1995; Sched. 1, Part 2 of the Endangered Species Protection Act, 1992), and locally in the ACT (ACT Government, 1998), and New South Wales (Sched. 12, National Parks & Wildlife Act, 1974). It is also categorised as Endangered in Victoria (NRE, 1999).

The first step of the recovery program for *D. impar* was a research project undertaken in 1988, which revealed much of this species' natural biology (Coulson, 1990). The resulting report highlighted the threatened status of the lizard, which initiated the development of

an Action Statement (Webster *et al.*1992). This document outlines the threats responsible for the decline and the conservation measures required for the recovery of this species. Concurrent with the Action Statement was the establishment of the Victorian Striped Legless Lizard Working Group (VSLLWG), which was subsequently named in the Action Statement as the body responsible for co-operative management actions in Victoria (Kutt *et al.*, 1995).

Melbourne Zoo has contributed immensely towards the success of the VSLLWG, in not only providing administrative co-ordination, but also in accomplishing three major roles. Firstly, it is a repository for salvaged animals rescued from sites destroyed by development. These specimens will become a reserve for future intended translocation programs. Secondly, the captive colony acts as a source for biological research, with the main emphasis placed on captive husbandry and breeding. Lastly, the role of education is probably seen as being the most effective approach towards creating public awareness of native grasslands (Banks, 1992). The involvement of the Melbourne Zoo is seen as a critical factor in the overall success of the Working Group to date (Kutt *et al.*, 1995).

MATERIALS & METHODS

All *D. impar* held at Melbourne Zoo are maintained under permits issued by the Victorian Department of Natural Resources & Environment.

Housing

A. Adult lizards were maintained in three different types of enclosures:

1.Inside the Reptile House in plastic Click Clack boxes (each measuring 300 x 210 x 105mm), with fly-wire mesh lids. The substrate consisted of 30-40mm of palm peat, with pieces of dry grass tussock resting on the top. Water was provided in small plastic bottle tops. The boxes were placed on wooden shelves in an off-limit area where the ambient temperature ranged from 15-25°C. Additional lighting was provided by 40W fluorescent tubes suspended 50mm above the tops of the containers.

2.Inside the Reptile House, in a different area to the plastic boxes, in an open-topped marine plywood enclosure measuring 2000 x 1000 x 500mm. This was landscaped with a 100mm substrate of palm peat and soil, small grass tussocks, rocks and large pieces of bark. Two 250W heat lamps were suspended over one end of the box to provide a thermal gradient. These produced floor temperatures of 40-45°C, beneath the lamps, to 20°C at the other end of the box. A small shallow bowl of fresh water was available at all times.

3.Outdoors in plywood enclosures, each measuring 1600mm long x 800mm wide x 600mm high. The tops are covered with fly-wire mesh and the bases have a drainage hole, which is also covered with fine mesh (Fig. 2). Access is either through the hinged tops or via smaller panels on the fronts of each enclosure, which are also covered with fly-wire mesh. The two sections of mesh allow for good ventilation and access to direct sunlight. Each enclosure can be divided in two by sliding a partition in place if required. The enclosures are covered with sheets of plastic during the winter months to prevent flooding from heavy rain.

Substrate consists of a 100mm layer of moist palm peat, which enables lizards to burrow and take refuge during hot weather. During winter it also acts as a medium in which to overwinter and provides relatively stable temperatures. Enclosure furnishings comprise 3-4 large, transplanted tussocks of Kangaroo Grass *(Themeda triandra)* and a 10-15cm mat of coconut fibre. A water bowl is provided and during warm weather water is sprayed over the boxes to allow lizards to drink directly from the vegetation. The boxes are portable and rest on wooden stands 1m above the ground in a secure off-limit area within the Zoo's Reptile House complex. They are positioned facing north-west to make maximum use of available sun. Since March

1999, following the removal of two large trees immediately to the west of this area, the amount of direct sunlight reaching these boxes increased dramatically, to between five and eight hours per day.

4.Outdoors in recycled plastic enclosures, each measuring 1200 x 740 x 750mm. The upper 390mm of each side is a hinged fly-wire panel, allowing good keeper access and ventilation. The top is fly-wire mesh over 10 x 10mm weldmesh, in a 55mm stainless steel frame. Landscaping is the same as in the outdoor plywood enclosures, with the substrate resting on a piece of plastic egg-crate, which, in turn, rests on eight circular pieces of plastic, each 20cm in diameter. These have a 20mm gap cut in them to allow moisture seeping through from the substrate above to escape. Like the outdoor plywood enclosures, these units also have two carry handles at each end to allow ease of transport.

B. Young lizards, including hatchlings, were maintained in the Reptile House under the same conditions as those initially provided for adult lizards, ie. in the plastic boxes.

A variety of live insects (i.e. crickets, grasshoppers, housefly and blowfly maggots, mealworms, termites, moths and isopods) is scattered in the enclosures 2-3 times a week. The sizes of the insects is closely monitored to ensure that they are not large enough to damage the lizards if the latter are not hungry.

Sexing

Animals were originally housed together according to provenance to maintain genetic integrity, though this inhibited the breeding potential within two small groups of single-sex animals. However, from 1996 onwards, lizards were placed together in mixed-sex groups to maximise breeding potential, noting that all the lizards were collected from around Melbourne and were classed as belonging to the same genetic cluster. This resulted in social groupings of 1:1 (one male and one female) to 1:3 and 2:2. Individuals were initially sexed using X-rays to check for a pair of post-cloacal bones, which are present in males and absent in females. This was discontinued in 1997, in favour of using the small "cloacal spurs", which are present under the hind-limb flaps in males (Rauhala & Andrew, 1998). Additionally, most specimens are individually identified by a numbering system of pyrobrands on the ventral scales, using the same system as adopted by Kutt (1992) and O'Shea (1996) for field studies on *D. impar* in Victoria.

Handling

Due to the nervous and cryptic nature of this species, lizards are handled infrequently to alleviate any possible problems arising due to stress. To minimise direct physical contact, lizards are weighed in self-sealed plastic bags, which also assist in identification of brands. Clear plastic bags are also used when taking body measurements. Lizards are placed in a bag and carefully pushed to the outer edge with a ruler until the body is straightened. The snout, tail tip and cloaca are marked on the bag to obtain accurate length measurements, which are recorded once or twice yearly. Adult lizards are weighed on arrival and usually once or twice yearly thereafter, particularly before entering brummation (late March-April) and on emergence (September). However, where weight losses were suspected, they were weighed approximately every 40 days until lizard weights stabilised. They are not disturbed between May and September. Food was occasionally introduced to the enclosures during this period of inactivity, if animals were observed basking during periods of unseasonally warm weather.

Lizards hatched at the Zoo are weighed and measured monthly for the first 12 months and at six monthly intervals thereafter.

Public display

A small group of lizards is exhibited to visitors in a specially designed all-glass enclosure 960mm long x 500mm wide x 480mm high. This is naturally landscaped with a palm peat, fine silica sand and soil substrate; *T. triandra*

tussocks and small rocks and logs. The top of the exhibit is in two sections - one fixed glass panel 250mm wide at the front and a rear removable perforated sheet metal section. The glass enclosure rests under a timber frame at the rear, which has a hinged lid above the rear section of the exhibit. This includes a 20W blacklight, two 20W down-lights and two mesh-covered panels, each 380 x 80mm, for ventilation. The down-lights produce temperatures of 30-35°C on top of the tussocks below. Additional ventilation is provided through two circular plastic mesh inserts, each 60mm in diameter, in the bottom of the exhibit's side walls.

At both ends of the exhibit itself is a curved panel 480mm high and 500mm wide. Positioned across the rear wall of the exhibit is an enlarged photograph of a grassland remnant close to Melbourne, with a chemical factory in the distance. This also "extends" across the front of both the side panels to create a grassland diorama. Superimposed on the photograph on the two end panels are blocks of text about native grassland, their current status and what Zoo visitors can do to assist in their conservation. The grassland landscaping inside the exhibit is extended "outside" the exhibit, through dried grasses and grassland flowers in front of the two additional panels (Fig. 3).

One male, and sometimes two, Southern Lined Earless Dragons, *Tympanocryptis lineata pinguicolla*, occupied the exhibit with the *D. impar.*

The whole display is in three sections, ie. the glass exhibit and the two side panels. It is also portable, to allow it to be used elsewhere inside and outside the Zoo, and rests on a specially designed table.

Incubation

Eggs were incubated in damp vermiculite (1:1 vermiculite and water by weight) in clear plastic containers, each 100 x 100 x 80mm. These were placed in a still-air incubator at 28-31°C.

RESULTS

Receipt of lizards

The first *D. impar* received at Melbourne Zoo, under the auspices of the Victorian Striped Legless Lizard Working Group (VSLLWG), arrived on 28 January 1991, from the Derrimut Grasslands Reserve (DGR), west of Melbourne. A further 69 lizards were received to the end of 1996, mostly in 1992 (17 arrivals), 1993 (20) and 1995 (22). No lizards were received in 1997 or 1998. In 1999, 38 lizards were received between 20 April and 13 September.

The majority of these lizards resulted from specific rescue operations carried out by the VSLLWG in the outer western suburbs of Melbourne:

13 of the 1992 arrivals from the loss of half of the Sunshine Grassland Reserve.

14 of the 1993 arrivals through the construction of the Western Ring Road and associated developments.

20 of the 1995 arrivals through ground-clearing for a new prison at Deer Park.

All of the 1999 arrivals from the development of the Albion Explosives Site (to a residential and town complex).

All other lizards were received as isolated rescues from or via VSLLWG personnel close to Melbourne or in western Victoria. The one exception to this was the transfer of six young lizards from the ACT Parks & Conservation Service in early March 1994. These had been hatched 19 days previously and were moved to the Zoo for rearing.

Of the 70 lizards received from the wild prior to 1999, 13 were males, 18 were females and 34 were unsexed. The 38 lizards received from the Albion site in 1999 comprised 11 males, 22 females and five unsexed. Of the unsexed lizards, three were juveniles with snout-vent lengths of 40-50mm, one was received with injuries in the cloacal area that prevented examination of cloacal spurs, and one died before it was measured and sexed.

Most of the lizards received from the wild were adults, although their arrival sizes and weights varied greatly. For example, 19 of the 20 lizards rescued from the prison site at Deer Park were adults with the following dimensions:

Weight: 2.04 - 6.00g (mean 4.19g)

Snout Vent Length: 74 - 110mm (mean 90.94mm).

Total Length: 80 - 310mm (mean 238.20mm; included a number of lizards with regrown tails of varying lengths and some which had lost their tails during the rescue operation).

Lizards were assumed to be adult if their snout-vent length was greater than 70mm.

Mortality

The majority of lizards received were in good condition, although some had been injured in the salvage operations. The latter usually involved a back-hoe to gently lift the large inground rocks, which is where many of the lizards were found. The back-hoe operators were quite skilful at this process and relatively few lizards were injured. Thirty eight of the lizards received from the wild from 1991-96 died. Of these, 12 (31.6%) died within one month of arrival and a further 10 (26.3%) within six months. Most of these deaths occurred in 1993 (11, or 28.9%), 1995 (10, or 26.3%) and 1996 (6, or 15.8%).

Single lizards died in 1991 and 1997, and there were no deaths in 1998 or 1999.

Departures

Eleven lizards were transferred out of the Zoo:

Eight lizards were sent to the South Australian Museum in March 1994 for genetic studies.

Three of the six lizards received from the ACT in 1994 were returned to the ACT in September 1999.

Captive Management

All lizards were housed in the small Click Clack boxes, 1-2 lizards per box, inside the Reptile House prior to September 1992, when the boxes were moved from the off-limit office area of the House to the central off-limit area. In December 1992, a group of 10 adult lizards was transferred to the large open-topped plywood enclosure, still in the central off-limit area. This was due to the increasing number of lizards received through salvage operations and also to begin establishing potential breeding groups and better observe natural behaviours.

Regular monitoring of the lizards in the open-topped enclosure showed that they preferred higher temperatures than expected, with 4-6 lizards often being found under the bark below the heat lamps, where the floor temperature ranged from 40-45°C during the day. Hence, all adult lizards were moved to the outdoor enclosures in August 1994. All young lizards and those hatched at the Zoo were retained indoors.

The outdoor enclosures were initially located on a shelf against the Reptile House's west-facing brick wall, and under a fibreglass overhang. However, this prevented morning sun from entering the enclosures and they were subsequently moved away from the wall and into an open area in December 1996. This new area received direct sunlight at regular intervals throughout the day and observations of lizards basking increased dramatically. Lizards were rarely seen during the May-September period and were assumed to be in the substrate or the bases of the grass tussocks, as encountered in the wild during the winter in Victoria (pers. obs.). However, there were two recorded instances of lizards basking in August during sunny afternoons when the air temperature was recorded at 14-15°C (pers. obs.).

The range and amount of live food offered to the lizards was also significantly increased during spring 1994, as most adult lizards which entered the collection prior to that time had lost weight. The pattern with a number of these lizards was loss of 10-30% of their arrival weight over the first 6-12 months in captivity, followed by approximately 12

months at their "new" weights, before starting to regain weight. With most individuals still alive, arrival weights were regained after 3.5-4 years. Lizards were observed to bask on the outer edges of the grass tussocks and, when disturbed, immediately sought refuge in the tussocks or in the small burrows they had created in the moist substrate. Hence, more insects were sprinkled throughout the tussocks, with particular care to provide these over the 1-2 months prior to brummation. This resulted in most lizards gaining weight during 1995-96. Those individuals which had not improved in condition were moved indoors from September 1996 to September 1997 and provided with additional heating and food.

Most lizards received after early 1996 showed very little weight loss and either maintained their arrival weights or increased weight after arrival.

Lizards held outdoors were transferred to the recycled plastic boxes during October-December 1999.

Public Display

Three of the lizards received from the ACT in 1994 were placed in the exhibit when it was completed in 1996. They proved to be excellent display animals, being readily visible at most times of the day, particularly in the mornings and early afternoons. They often basked together on top of one of the grass tussocks, where temperatures of 30-35°C were achieved, but could also be seen in other parts of the display. These lizards often fed on the live insects offered when keepers were present and could even be induced to occasionally take these items from forceps.

Four interactions were observed between the *D. impar* and the *T. lineata pinguicolla* in 1997:

Late in the afternoon on 4 May, keepers were observing the lizards and saw one of the legless lizards move across the dragon as the latter was basking on top of a rock. As it moved over the dragon's body, the dragon shook the legless lizard off, puffed up its body with its mouth wide open and moved quickly towards the legless lizard's head. There was no contact with the legless lizard's head, but this action caused the latter to fall off the rock and then move off to another part of the exhibit. The dragon remained on the rock.

On 10 June, a legless lizard was observed coiled around the body of the dragon. Both were resting on a rock and no aggression was apparent from either lizard. The lizards had moved apart when next seen about one hour later.

In early October when feeding the group of lizards with small live crickets, one legless lizard seized a cricket and commenced to eat. This lizard was approached by the dragon, which seized the cricket and pulled it out of the legless lizard's mouth and ate it, whereupon the latter squeaked vigorously for the next five minutes until the dragon moved off.

In November, a legless lizard was seen with its head inside the dragon's mouth, taking an insect that the latter was eating.

However, there was no evidence of injury inflicted on any of the lizards, of either species, by its cage-mates.

Egg laying and hatching

Eggs were successfully incubated and hatched on three occasions:

Two eggs were laid overnight by a female collected at the DGR on 22 December 1990, as part of an ecological study of the species. Both eggs hatched (Table 1).

Two eggs were laid by a female collected at the DGR on 17 December 1991, as part of the same ecological study as the first clutch (above). Both eggs hatched (Table 1).

Two clutches, each of two eggs, were laid together in a cavity on the surface of the palm peat substrate in one outdoor enclosure at the Zoo on 17 December 1997. A layer of coconut fibre covered the egg deposition site. Females were frequently seen occupying the site for some weeks prior to laying. Three of

Table 1. Egg Dimensions and Incubation for *D. impar* at Melbourne Zoo

Oviposition Date and No. Eggs	Egg Wt. (g)	Egg Dimensions (lengthxwidth,mm)	Inc. Temp. oC	Inc.Period (days)
22Dec. 1990 (2)	0.65	18 x 8	25-31	38
	0.65	18 x 8		
17 Dec. 1991 (2)	0.7	19 x 8	28-31	47
	0.7	19 x 8	28-31	47
17 Dec. 1997 (2)	0.80	20 x 8	29-30	42
	0.90	22 x 9	29-30	42
17 Dec. 1997 (2)	0.95	23 x 9	29-30	42
	0.8	22 x 8 (infertile)	29-30	42

the eggs were fertile and all hatched after 42 days at 29-30oC. The four eggs averaged 0.86g, 8.5mm in width and 21.9mm in length (Table 1).

Only three adults occupied this enclosure, the male originating from the Sunshine Grassland reserve on 18 September 1992 and the two females from the Deer Park "prison site" on 2 and 7 August 1995. Prior to laying the females weighed 5.68g and 6.31g on 18 November 1997. Two days after laying, these females weighed 4.65g and 4.79g respectively.

The mean egg dimensions at laying were 0.77g (0.65-0.95, n=8), 20mm long (18-23, n=8) and 8mm wide (8-9, n=8).

Growth of young

Growth data was collected on seven young lizards from hatching to at least 18 months of age (Table 2), corresponding to the three clutches of eggs referred to above. Hatchlings varied from 0.25-0.71g and 32-41mm snout-vent length. These had increased to 0.90-1.98g and 55-59mm snout-vent length at 12 months of age. Three of the lizards hatched at the Zoo died, ie. from the first clutch after two months and from the second clutch, after three years and three years ten months. One of the lizards from the first clutch of eggs is still alive at the time of writing and is now over eight years old.

Data was also collected on the group of lizards received at 19 days of age from the ACT in 1994.

Most of the young lizards fed and grew well, and did not present management problems. The three young lizards which hatched on 28 January 1998, first sloughed after 3-18 days. No other data on sloughing was able to be recorded due to the lizards' secretive nature.

DISCUSSION

Although some difficulties were encountered in successfully maintaining *D. impar* at the Zoo prior to August 1994, changed husbandry practices since then have ensured that lizards which arrive in good condition can be maintained without difficulty. Four factors have been shown to be critical to the successful captive maintenance of this species:

The lizards must have access to temperatures of 35-40oC for basking.

Live insect food must be very plentiful and be of the appropriate type and size.

Presence of grass tussocks, preferably *T. triandra*.

Suitable deep substrate, which provides good insulation against temperature extremes.

The failure to provide adequate temperatures for the lizards, combined with inadequate levels of food are thought to be the main reasons for the failure of a number of lizards to thrive prior to August 1994. Pygopodids would seem to be quite tolerant of high temperatures and critical thermal maxima of 43.3°C and 45.9°C have been recorded for *Delma inornata* and *Lialis burtonis* respectively (Greer, 1989). The only species in which thermoregulation has been studied, *L. burtonis*, was found to have an average preferred body temperature of 35.1°C (Bradshaw *et al.*, 1980). A number of pygopodids have been observed basking in sunlight, including *D. impar* and *Aprasia sp.* (S. Hadden and M. O'Shea, pers. comm.; Martin, 1972). Ehmann (1981) has also observed *Ophidiocephalus taeniatus* under warm litter below a heat source in captivity.

Clearly also, some lizards were received with injuries resulting from the salvage operations and these are unlikely to have survived anyway. Given the nature of the landscaping in the boxes and the lizards' naturally secretive behaviours, those specimens that died were not usually found in a state where post-mortems could be undertaken. However, in light of the measured weight losses prior to 1995, it is reasonable to assume that inadequate diet was the most likely cause of death for otherwise uninjured lizards.

Field studies of the diet of *D. impar* indicate that the species feeds mainly on spiders, crickets, Lepidopteran larvae and cockroaches (Coulson, 1990; Nunan, 1995; Kutt *et al.*, 1998). Nunan (1995) suggested that these lizards may be both active foragers and adopt a sit-and-wait ambush feeding strategy. Observations of the captive lizards at Melbourne Zoo support both strategies.

Arrival weights and regular weighing of lizards was found to be the most effective method of monitoring general condition and can be undertaken with minimal stress on the animals.

From observations at the Zoo, the chance of breeding this species is enhanced if:

Food intake is increased prior to brummation.

A friable, slightly damp, deep (10-20cm) substrate is provided, to allow creation of burrows and small depressions for egg-laying.

Lizards are exposed to natural climatic changes, rather than constant temperatures. This includes the capacity to brummate over winter.

Almost nothing is known about the population dynamics of pygopodids and there are no records of sex ratios in wild populations of *D. impar*. The finding of twice as many females as males during salvage at the Albion site close to Melbourne may indicate that there are more females than males, at least in this population of *D. impar.* However, this is not indicative of a trend and Rauhala (1999) noted that sex ratios of *D. impar* in the ACT at single, but different sites, ranged from 7:1 in 1995, 1:1 in 1996, and 3:1 in 1998. Two of these findings are based on field trapping programs, whilst the other arises from a salvage operation. It may also be the case that different male: female ratios will be encountered at different times of the year, although most trapping programs are implemented from late September to early February. Greer (1989) noted that female *Lialis* sp. are more often encountered than males.

Very little information has been published on reproduction in pygopodids and what there is relates mostly to clutch size and size of eggs (Greer, 1989), with only three references to incubation times and temperatures, ie. *Delma australis* and *D. fraseri* (Bush, 1985), *D. grayi* (Maryan, 1998) and *Pygopus lepidopdus* (Fitzgerald, 1983); and two references to hatchling size, ie. *D. grayii* (Maryan, 1998) and *P. lepidopodus* (Wells & Husband, 1979). Hence, the hatching of three *D. impar* at Melbourne Zoo in January 1998 would appear to be the first full captive breeding of this species and perhaps of any species in this genus. Although copulation was not observed, the parents had been in the Zoo for 2-5 years (male for five years and both females for two

years) prior to the eggs being laid.

Sexing these lizards proved problematic until the presence/absence of "cloacal spurs", which resemble enlarged thickened scales, was fully explored. Rauhala & Andrew (1998) showed that this method of sexing could be applied to *D. impar* and it was subsequently used for the specimens at Melbourne Zoo.

The *D. impar* eggs laid at the Zoo were larger than those recorded from *D. australis, D. tincta* and *D. torquata* (Bush, 1985; Kluge 1974), but smaller than those recorded from *D. grayii* and *D. fraseri* (Bush, 1985; Maryan, 1998). The incubation periods, of 38-47 days, was shorter than any recorded to date for pygopodids at similar incubation temperatures (Greer, 1989; Maryan, 1998).

Recording lizards as adult if their snout-vent length exceeded 70mm was based on captures of wild specimens carrying developing eggs in the ACT over a number of years (Rauhala, 1996 & 1997). The listing of snout-vent lengths in adult *D. nasuta*, a similar sized species to *D. impar*, as 71-90mm for males and 74-89mm for females (Patchell & Shine, 1986), suggests that 70mm is a reasonable assumption for minimum size in adult *D. impar.* On that basis, the *D. impar* hatched at the Zoo became adult at 3-5 years of age. Porter (1998) recorded third cohort wild *D. torquata*, a slightly smaller species than *D. impar*, as having average snout-vent length of 65mm. Given that this species is recorded as having a snout-vent length of 60mm (Cogger, 1992), specimens of 65mm SVL could well be considered of breeding size.

Longevity in pygopodids is barely known. A *D. inornata* lived for over five years and a *Pygopus nigriceps* for almost seven years (in Greer, 1989). Five of the *D. impar* at Melbourne Zoo, as of 15 September 1999, have been held for over five years and arrived as adults. One of these lizards, which was hatched at the Zoo on 28 January 1991, is eight years and eight months old. The three lizards returned to the ACT in September 1999, at four years and seven months of age, were presumably only young adults. On the basis of this data, therefore, even though it is based on captive animals, it seems reasonable to suggest that *D. impar* can live for at least 12 years and possibly up to 20 years of age.

Melbourne Zoo's success with maintaining, displaying and breeding *D. impar* has contributed significantly to current knowledge of this species. It has also achieved important goals in the Striped Legless Lizard National Recovery Plan (Smith & Robertson, in press) and filled some of the gaps in life history knowledge that were encountered when a Population & Habitat Viability Assessment (PHVA) was undertaken in 1996 (ARAZPA, 1996).

Studies of the captive lizards are ongoing, including exploration of effective tracking techniques that will be necessary for translocation and re-release programs. The latter are still at the trial phase, involving the implantation of very small harmonic direction finder diodes in specimens of the related *Delma inornata*.

The Striped Legless Lizard is seen as a flagship species for the native temperate grasslands and their conservation. It is also a critical component of Melbourne Zoo's broader grassland conservation program, which extends to other fauna, such as the Eastern Barred Bandicoot (Myroniuk, 1995), and flora, including endangered grasslands themselves and membership of three threatened grassland orchids recovery teams (Arnott, 1996).

The information gained from captive animals, combined with the current knowledge from field research, will greatly assist with furthering what is at present a growing understanding of this species cryptic habits.

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Table 2. Growth of *D. impar* at Melbourne Zoo

	Age	Weight (g)	SVL (mm)	Total Length(mm)
Group 1	Hatching	0.25	32	80
(2 eggs laid	1 month	0.25	34	85
22 Dec.	3 months	0.50	39	102
1990 and	6 months	0.90	45	131
hatched 28	12 months	1.40	55	161
Jan. 1991)	18 months	1.40	57	166
(*)	2 years	1.40		
	3 years	1.30		
	5 years	4.06	77	248
	6 years	4.30		
	7 years	4.89	78	254
	8 years	5.61		
Group 2	Hatching	0.70	41	115
(2 eggs laid	1 month	0.65	41	115
17 Dec.	3 months	0.70	42	121
1991 and	6 months	0.80	45	131
hatched 1	12 months	0.90		139
Feb. 1992)	18 months			
(**)	2 years			142
	3 years	2.40		
Group 3	Hatching	0.71	40	112
(4 eggs laid	3 months	0.86	45	126
17 Dec.	6 months	1.14	46	137
1997 and 3	12 months	1.98	59	176
hatched 28	18 months	2.62	62	195
Jan. 1998)				

(*)1 lizard died 10 April 1991

(**)1 lizard died 22 Jan. 1995 and other on 13 Dec. 1995

Figure 1. The Striped Legless Lizard, *Delma impar*.(photo, Chris Banks)

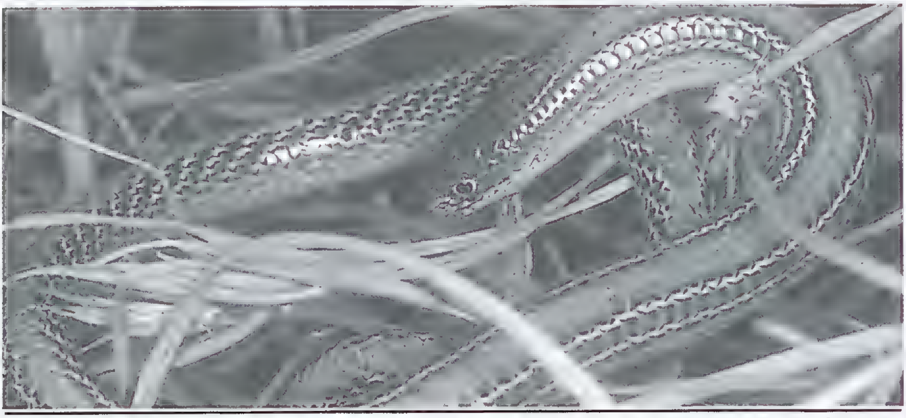


Figure 2. Outdoor plywood enclosures for *Delma impar* at Melbourne Zoo.(photo, Chris Banks)

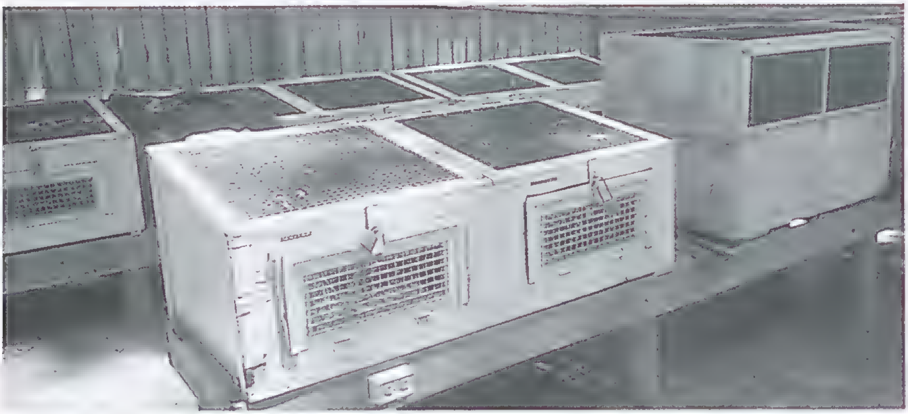
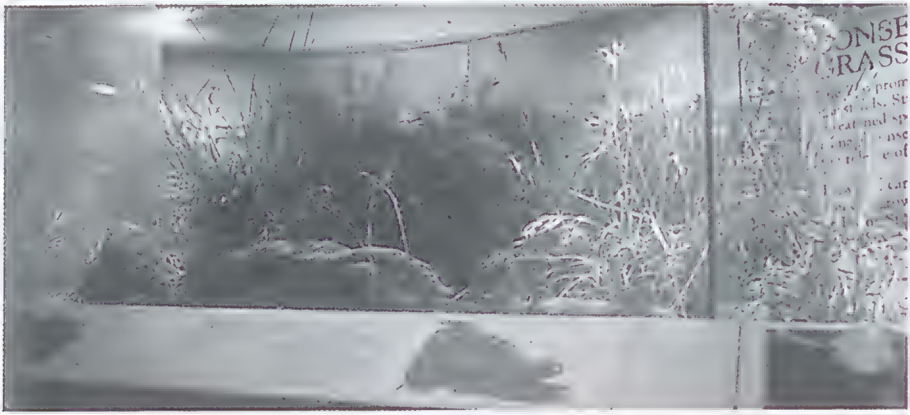


Figure 3. Public exhibit for *Delma impar* at Melbourne Zoo.(photo, Chris Banks)



CAPTIVE HUSBANDRY AND BREEDING OF THE SHORT-TAILED GOANNA *VARANUS BREVICAUDA* AT THE ALICE SPRINGS DESERT PARK

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INTRODUCTION

The Short-tailed Goanna *(Varanus brevicauda)* (Figure 2) is the world's smallest species of goanna, adults reaching about 110 mm snout - vent length with a tail of about the same length. Wild specimens typically weigh between 8 and 15 grams. The lizard is found in spinifex *(Triodia spp)* dominated sand country in the central Australian part of its range (James, 1996). The species has not previously been kept in Australian Zoos or Wildlife Parks and rarely in private collections. It remains little known on the world stage. Alice Springs Desert Park has maintained this diminutive species for over 3 years and has recorded some useful data on its maintenance and breeding.

ACQUISITIONS FOR ALICE SPRINGS DESERT PARK

The *Varanus brevicauda* held at Alice Springs Desert Park (ASDP) were collected from the wild at a sand plain / sand dune site vegetated with *Triodia* grasses with a mixed shrub overstorey about 35 kilometers south of Alice Springs (Figure 3). This species is very secretive and is rarely observed active on the surface, even though its tracks indicate substantial surface activity (James, 1996). The most successful method of capturing these lizards is in pitfall traps or funnel traps used with a drift fence.

SEX DETERMINATION

Sex determination in this species is difficult. We have tried "spur" size/condition, manual "popping" of hemipenes and watching behavioural interactions to try to accurately sex our animals. No technique has been entirely successful.

In some males, the little cluster of spiny scales ("spurs") on either side of the tail near the vent are slightly larger and more spinose on the free edge (by feel, not sight) than in other lizards. However, some animals that evert hemipenes when manually "popped" also have relatively little development of the spinose free edge to this cluster of spiny scales.

Manual "popping" of hemipenes is also unreliable. Sometimes an eversion can be achieved and other times not. Consequently each animal must be checked many times, which increases the potential for injury and still doesn't guarantee a definite result. We have found it easier to achieve eversion in animals that are active and hot.

Behavioural observations have worked for us occasionally. A suspected male can be placed in the same cage as our known adult male; if the resident attacks or bites the newcomer aggressively, we assume the introduced lizard is a male. If the resident male ignores or tries to mate the newcomer, it could be a female or a sub adult male. Some lizards which have been ignored or had mating attempts directed at them by the larger male have subsequently been manually "popped" as males.

The best method of sex determination for this species could be radiographs of the tail region in sub adult and adult lizards to look for hemipenal bones in male lizards however we have not tried this as yet.

BREEDING MANAGEMENT

The captured animals were adults or sub - adults. Initially, our animals were kept under "normal" conditions with a basking spot of 35°C and both blacklights and white fluorescent lights. A variety of enclosures were used to house these lizards including glass fronted wooden reptile boxes and various sized clear or opaque plastic tubs. Water was always

available in a shallow dish. Feeding and activity were episodic, with the animals hiding away for days at a time. No breeding behaviour was noticed under these conditions.

In late February 1998 we decided to try the "Retes Method" of goanna husbandry (Frank Retes, a private herpetoculturist in the USA, has pioneered a new regime of goanna husbandry). A hot basking spot on the substrate of 45°C was provided with an incandescent globe and reflector. A stack of boards, with spaces between boards, was provided for climbing and shelter. These boards were placed adjacent to the hot spot on the substrate. All this was set up in a plastic "tub"(60 x 40 x 40 cm) with a 150 mm deep moist sand substrate and no additional lighting (Figure 4). (Retes, 1996 a, b). Unlike Retes however, we did not illuminate the enclosure 24 hours a day (14 hour day: 10 hour night) and we fed good quality (vitamin/calcium supplemented) food every 2 - 3 days versus low quality food available at all times. Retes also positions the spot lamp over the stack of boards, but as *V. brevicauda* is a burrowing species we placed the spot over a section of the substrate.

A pair of lizards was introduced to this enclosure, and they immediately began to eat regularly and remain active throughout the day. They regularly basked under the hot spot lamp for periods of up to 5 minutes many times each day. The lizards were fed dusted roaches, mealworms or mealworm pupae every 2 to 3 days. Condition of both animals improved rapidly and courtship behaviour was noted within 6 weeks.

When males and females were kept together and offered abundant food, the males became obese (exceeding 20 grams) because they ate whenever food was offered; even if it was meant for the females. Females rarely got obese because they put excess condition into egg production. Males may need to be separated at feeding times to control food intake and prevent obesity.

BREEDING ACTIVITY

Courtship behaviour was noted in early March 1998 and mating was observed on 9/3/98. Four eggs were laid on 10/4/98 (only 2 were fertile) and one egg hatched on 30/6/98 after 80 days at 30°C in an incubator. A second clutch of 3 eggs was laid on 8/11/98 (mating recorded on 13/10/98) and these all hatched between 18/1/99 and 20/1/99 (71 to 73 days) at an incubator temperature of 31°C.

Table 1 Egg laying data for clutches 1 and 2.

Clutch 1	Egg length	Egg width	Egg mass	Fertile?	Date laid	Date hatched	Incubation temp
Egg 1	-	-	1.66 g	y	10/4/98	30/6/99	30°C
Egg 2	-	-	1.80 g	y	10/4/98	-	30°C
Egg 3	-	-	2.52 g	n	10/4/98	-	30°C
Egg 4	-	-	0.94 g	n	11/4/98	-	30°C
Clutch 2							
Egg 1	23 mm	12 mm	2.07 g	y	8/11/98	18/1/99	31°C
Egg 2	25 mm	12 mm	2.13 g	y	8/11/98	20/1/99	31°C
Egg 3	24 mm	12 mm	2.19 g	y	8/11/98	20/1/99	31°C

Egg length, width and mass recorded on day of laying.

Table 2 Hatchling lengths and weights for clutch 1 and 2.

		SVL (mm)	Tail L (mm)	Mass (g)
Clutch 1	Hatchling 1	43	39	1.12
Clutch 2	Hatchling 1	55	49	1.80
	Hatchling 2	55	49	1.83
	Hatchling 3	55	49	1.71

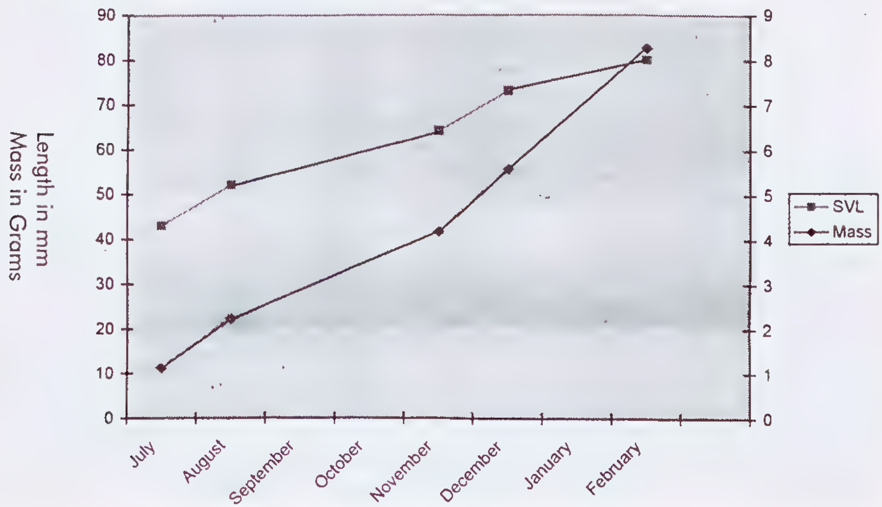
Hatchling measurements taken on day of hatching or following day.

The hatchlings were set up in a similar fashion to the adult pair with a stack of shelter spaces and a hot spot basking area. The juveniles progressed very well and were eager feeders every 2 to 3 days. At 7 months of age, the first hatchling had grown to adult size (80 mm SVL and 8.25 grams) (See Fig 1.). When placed with an unrelated adult male, it was actively courted. The three hatchlings from the second clutch have had a similar growth rate. One died at one month of age due to intestinal rupture (from eating too much?). At eight months of age the two surviving juveniles are around adult size at 77 and 81mm SVL and 6 .77 and 8.03 grams respectively. This data is in accord with that recorded by James (1996) for maturation size, hatchling size and clutch size. Similarly, our data confirm the observations of Schmida (1974) on clutch size, incubation period and hatchling size.

BREEDING ON DISPLAY

Following the laying of the second clutch of eggs the male and female adults involved in the breeding were transferred to a display exhibit which also contained Thorny Devils *(Moloch horridus)*. This exhibit is 1.8 metres wide, 1.2 metres deep and 3.0 metres high. It receives natural daylength via a skylight and gets white and ultraviolet light from a 250 watt metal halide light, while a hot spot on the substrate is provided by an incandescent spotlight. The substrate is red sand and decoration includes termite mounds, *Triodia*

Figure 1. Growth rate of neonate *V. brevicauda* hatched 30/6/98



grass clumps, dead branches and small shrubs (Figure 5). This exhibit was not initially set up to achieve the high basking temperatures required by the goannas and their subsequent feeding and behaviour reflected this. Both animals became inactive and only ate offered food occasionally.

In early May 1999, the exhibit was changed by adding more red sand to increase the depth to about 150mm and a higher wattage (375 watts) incandescent basking light was added to increase the basking spot temperature to the 40°C mark. The substrate was watered every second day to ensure the goannas had a suitable burrowing medium. The effect of these changes was dramatic, the lizards immediately responded by increasing their activity levels and consuming offered food much more regularly. Both animals increased weight noticeably until 17/6/99 when the female was noted to have lost weight and was looking "hollow". As this is considered a good sign that eggs have been laid; we were confident that she had deposited eggs somewhere in the tunnels the lizards had dug in the substrate. It was not practical to dig up the eggs, and as any more young from this pair would be surplus to our needs, we were happy to leave the eggs in the exhibit. It was not known if the conditions in the exhibit would be suitable for egg incubation as the exhibit has a thermostatically controlled sub-floor heater set to 30°C which may dry out the eggs.

On the 24/8/99 (68 days after the female was noted to have lost weight) we found a healthy neonate running about in the exhibit in full view of the adult male. The male showed no interest in the neonate goanna. It is unknown how many eggs were laid or how many hatched. Previous clutches from this female consisted of three and four eggs. The male may have been satiated or simply ignored the hatchling. While we cannot be sure of the incubation period or temperature in this instance, it seems likely that development was more rapid than in the previous two artificially incubated clutches. The hatchling weighed 1.42 grams and was 49mm SVL (measured on day of discovery) which is within the weight / size range recorded for animals in clutch 1 and 2.

THE FUTURE

ASDP now maintain 3.3 wild caught *V.brevicauda* and 0.0.4 captive-bred animals. We will attempt to breed all our wild caught founders in the coming years.

Despite the infrequent sightings and secretive nature of this animal in its natural habitat, captive animals quickly settle down to become incredibly bold and active, making this species a good choice for display. Because of its small size, this lizard can be displayed with other medium to large sized lizards such as Netted Dragons *Ctenophorus nuchalis*, Thorny Devils *Moloch horridus* or maybe some of the medium sized skinks like the Night skink *Egernia striata*.

Future work on this species at ASDP will attempt to determine incubation length and temperature variables, growth rates of neonates and longevity of the species in captivity.

AKNOWLEDGEMENTS

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Figure 2. *Varanus brevicauda* from Uluru, N.T.

Figure 3. *V. brevicauda* trapping site near Alice Springs, N.T.

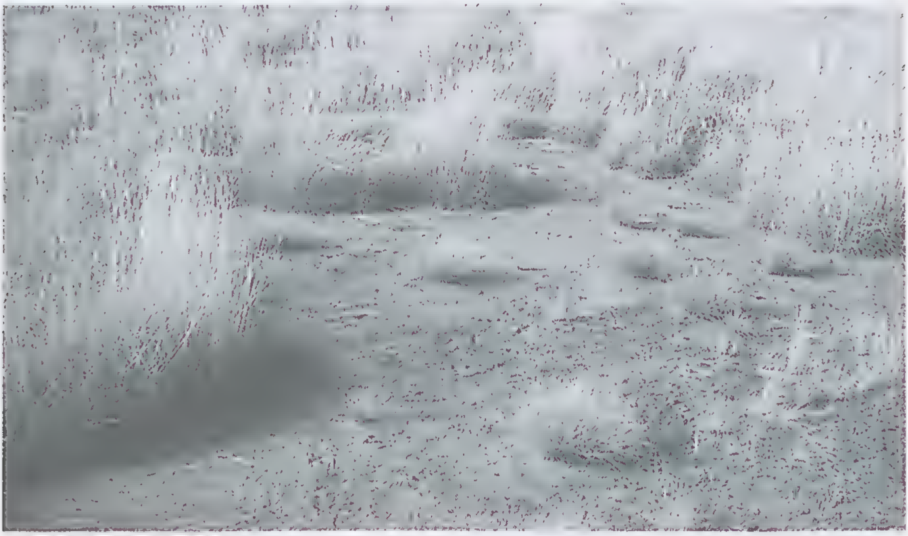


Figure 4. Breeding cage set up.

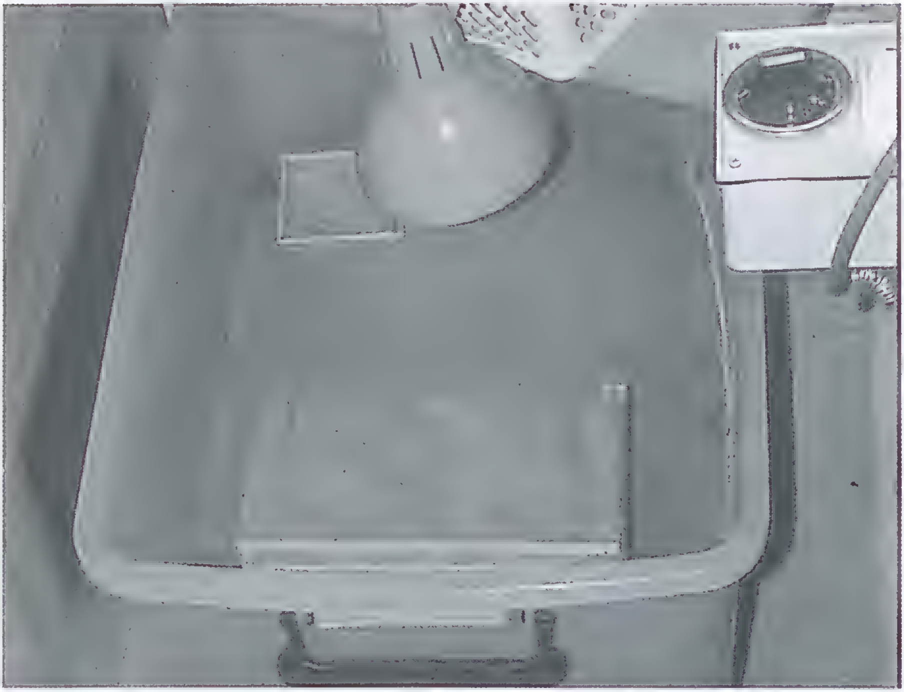
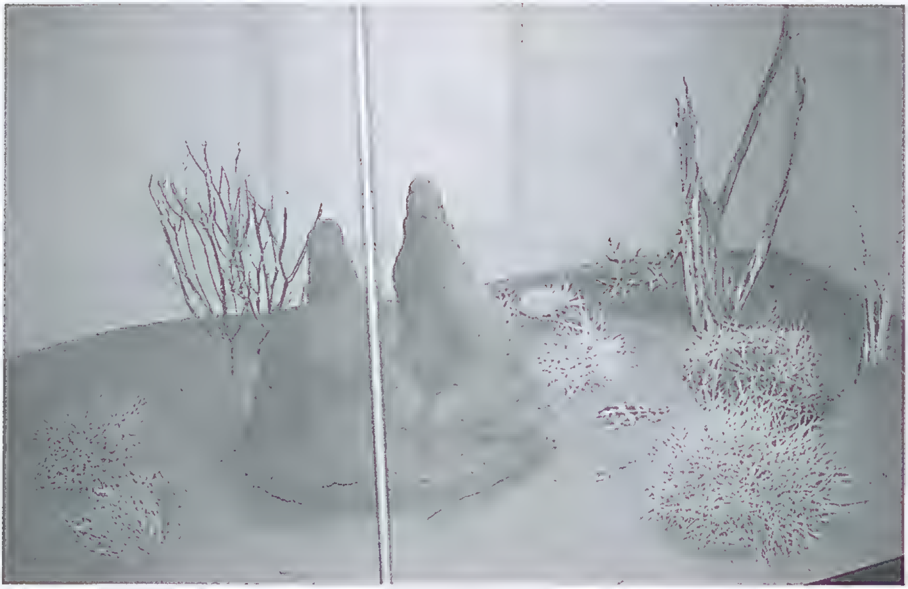


Figure 5. Public exhibit for *V. brevicauda*.



INITIAL OBSERVATIONS AND SURVEY RESULTS OF FRESHWATER TURTLES IN THE GREGORY RIVER AND LAWN HILL CREEK, NORTHWESTERN QUEENSLAND

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ABSTRACT

The turtle fauna of many of the rivers in northern Australia, particularly those that discharge into the Gulf of Carpentaria is poorly known. In June 1999 surveys for turtles were carried out at sites on the Gregory River and Lawn Hill Creek, near the Queensland-Northern Territory border. The surveys employed trapping and snorkelling censuses in parallel at reference sites covering six aquatic habitats.Worrell's Turtle *Emydura worrelli* was the most common and most widespread turtle encountered; these turtles were most abundant in slow-flowing, open river sites. Gulf Snapping Turtles *Elseya lavarackorum* were uncommon in open river sites but were more abundant in Lawn Hill Creek in areas associated with tufa dam habitats. Saw-shelled Turtles *Elseya latisternum* were only collected in the upper reaches of the Gregory River. Observations of free-swimming turtles provided information about the diet, behaviour and trapability of each species. Standard barrel traps were found to be inadequate to survey Gulf Snapping Turtles.

INTRODUCTION

The Gulf Snapping Turtle *Elseya lavarackorum* was originally described from fossils found near the modern-day Gregory River at Riversleigh (White and Archer 1994). The type specimen consisted of an almost complete, crushed shell. It was recovered by volunteer workers Sue and Jim Lavarack during the 1989 Riversleigh expedition. The fossil was found in an ancient channel of the Gregory River along with the remains of crocodiles, *Megalania* and large marsupials (Archer *et al.* 1989). The deposit was early Pleistocene and the presence of *Diprotodon optatum* suggested that the deposit may be 25,000 years old (Archer *et al.* 1989.)

The Gregory River and associated rivers of the Gulf of Carpentaria have been surveyed repeatedly for native fauna, including turtles. Prior surveys (e.g. Kennett and Georges 1989) had located undescribed species but no trace was found of the Gulf Snapping Turtle. The species was presumed to be extinct until 1995 when a chance observation of a large turtle in Lawn Hill Creek (E. Van Duys pers. obs.) spurred an impromptu search of Lawn Hill Creek and the Gregory River that year. The first live Gulf Snapping Turtle was collected by the author in Lawn Hill Creek (White 1996). In the same period, a shell of a recently dead Gulf Snapping Turtle was found in flood debris on the Gregory River. Since then specimens of the Gulf Snapping Turtle collected from the Gregory and Nicholson Rivers have been found in museum collections (Thomson *et al.* 1997).

In 1998, the first targeted searches were made to better determine the distribution and abundance of the Gulf Snapping Turtle. These surveys were concentrated in areas where the turtles were known to occur; the Gregory River and Lawn Hill Creek. Much of the survey work was carried out by volunteers under the Earthwatch program or supported by Pasminco Mining. The surveys also sought to determine why Gulf Snapping Turtles were under-represented in Museum collection; traps were set in a variety of aquatic habitat and a variety of trap baits were tested to see if this affected the nature of the catch. Concurrent with the trapping surveys, teams of snorkellers carried out visual surveys in the same habitat areas.

In addition to the search for Gulf Snapping Turtles, the surveys also sought to help resolve the species identity of some of the short-necked turtles in the Gregory River and Lawn Hill Creek. For this reason an opportunistic survey was conducted at Ixion Creek on the upper Gregory River. Tissue samples were also taken from the yellow-faced and red-faced *Emydura* for further genetic study. The aim of this study will be to test the relationship of the colour morphs of *Emydura worrelli* (Cann 1998) and to determine whether sibling species (namely *Emydura tanybaranga*) might also be present.

METHODS

Turtle censuses in the Gregory River were carried out using parallel survey methods; baited traps and snorkelling transect were carried at pre-determined reference sites. Reference sites were chosen which represent a range of aquatic habitats. Observations of turtle behaviour and responses to traps and bait types were carried out in areas away from the reference sites. Captured turtles were measured and notes made of distinguishing marks, scars or shell damage. All *Emydura* species were toe clipped to provide material for a genetic study (see below).

Survey Locations:

All turtle survey sites were located in the Gulf of Carpentaria drainage in far northwestern Queensland, near the Northern Territory border. Turtle surveys were carried out in three areas: the middle section of the Gregory River near Riversleigh Station, at Lawn Hill Creek in Lawn Hill National Park and at the junction of Ixion Creek and the Gregory River (Figure 1).The first two locations were chosen as these were areas where Gulf Snapping Turtles had been previously recorded; the Ixion Creek site was surveyed as the opportunity was made available to conduct a brief, comparative survey in the upper reaches of the Gregory River.

Timing of Survey:

A total of 13 days survey time was available between the 16th of June and the 30th of June 1998. Of these 10 days were dedicated to intense surveys along the middle Gregory River at Riversleigh, 1 day was devoted to surveys in Lawn Hill Creek at Lawn Hill National Park and 2 days were devoted to surveys of Ixion Creek and the upper Gregory River.

Reference Sites:

Survey reference sites were established on the middle Gregory River and at Lawn Hill Creek. Reference sites included a range of habitat types and will be re-sampled on an annual basis as part of a long-term study of turtle populations. On the Gregory River at Riversleigh we surveyed five replicas of two water depths (< 2m and >2m) in three habitats: river edge, mid-river and tufa dam. Tufa dams were limestone barriers that formed across the river channels creating natural weirs.

At Lawn Hill Creek only four habitats were surveyed, these being shallow and deep-water tufa dams (single reference site) and shallow and deep-water river edges (Two reference sites for each).

Four habitat types were surveyed in the upper Gregrory drainage, two in Ixion Creek and two in the confluent, upper Gregory River. At Ixion Creek, a new habitat type was surveyed; still-water creeks (lagoons). Tufa dams were not present in this section of the Gregory River. Reference sites were established along the edges of the upper Gregory River (two each of deep and shallow water sites) and in the still-water (Ixion) creek (single deep and shallow water sites).

Trapping Methods:

Traps were used in all of the reference sites on the Gregory River at Riversleigh as well as in Ixion Creek and the upper Gregory River. Trapping was not possible at Lawn Hill Creek and all survey results for this area are based on snorkelling surveys, observations and hand-capture data.

Mesh-lined barrel traps were used to survey turtles. Each trap was 1.3 metres long and 50 cm in diameter with a 30 cm funnel entrance. Traps set at reference sites were baited with tinned sardines. Each trap was submerged after being baited and checked at hourly intervals between 8.00a.m. and midnight. (Figure 2) The baits were replaced each morning when the traps were reset. Traps remained in place for 5 consecutive days at Riversleigh before being relocated. This meant that each habitat type on the middle Gregory River was sampled for a total of 400 hours. At Ixion Creek and the upper Gregory River traps remained in place for 2 days only (i.e. a total sample time of 64 hours for river edge habitats and 32 hours for the still-water creek areas).Turtles that were captured were identified, measured and released. In addition, the facial colouration of the *Emydura* turtles was noted and a tissue sample taken.

Snorkel Survey:

Snorkellers were used during daylight hours to carry out visual surveys of reference sites. Snorkelling surveys were not carried out when traps were present in the reference site. Surveys were conducted twice a day at each site. Each swimmer spent thirty minutes in the morning and thirty minutes in the afternoon surveying an area 25 metres around each trap site. Each reference site on the Gregory River at Riversleigh was thus surveyed by snorkellers for five hours (i.e. each habitat type was surveyed for 25 hours). At Lawn Hill, river edge habitat was surveyed for a total of two hours while the tufa dam habitats were surveyed for one hour only. At the upper Gregory River shallow and deep river edge habitats were surveyed for four hours each.

During the surveys swimmers were required to swim quietly around the reference site using only their flippers for propulsion. Surveyors stayed on the periphery of the reference area unless there were obstructions (such as log jams, tree roots or thick vegetation) that blocked vision. In these instances, swimmers were permitted to examine the obstacles at close range and look for sheltering turtles. Turtles were captured by hand (Figure 3) and quickly transferred to an assistant who measured and processed the turtle before releasing the captured animals at the end of the survey period.

Apart from recording turtle numbers in the reference sites, swimmers also made observations of turtle behaviour around the traps, recorded turtle occurrence in parts of the river, recorded turtle feeding behaviour away from the traps and captured turtles for measurement and tissue collection.

As mentioned above, snorkelling surveys were the only survey methods employed at Lawn Hill Creek. Snorkelling surveys were not employed at Ixion Creek due to poor visibility, but they were carried out in the nearby upper Gregory River.

Comparison of Baits:

Four bait types were tested in a separate survey activity. Traps were set along a uniform section of the edge of the middle Gregory River, 1 kilometre upstream from the Riversleigh causeway. The traps were set in water between two and four metres deep. The baits tested were sardines, pilchards, dog food (chicken) or the carcasses of road-killed mammals. Five traps were baited using each bait type. The traps were set twenty metres apart along the river bank and the bait type placed in each trap was randomly chosen. The traps were checked hourly for an eight hour period for one day. The number and species of turtle captured was recorded.

Tissue Sampling

Tissue samples were taken from all of the *Emydura* turtles that were caught in the traps. A small piece of the skin flap behind the smallest toe was removed and placed in sealable vials containing 70% ethanol. The wound usually did not bleed but the exposed area was sealed with skin glue (Vet Bond). As soon as the skin glue was dry the turtles were released. The tissue samples were forwarded to Assoc. Prof. Arthur Georges (University of Canberra) where they will be used in a genetic study of these turtles.

RESULTS

Trap Surveys of Reference Sites:

a) Gregory River at Riversleigh

Eighty seven turtles were trapped in the reference sites on the middle Gregory River. All of the turtles caught were Worrell's Turtle *Emydura worrelli* (Table 1). Most turtles were caught in deep water sites close to the river's edge. Eleven turtles were re-trapped during the survey period.

The average curved carapace length (and standard deviation) of the Worrel's Turtles that were trapped was 22.3 + 0.7cm (n=87) whereas the average length of these turtles caught while snorkelling was slightly greater (23.4 + 1.2cm, n= 28).The sizes of turtles greater than 10 cms (i.e. adults) ranged from 16.3cm to 23.8cms. The proportion of red and yellow facial markings on the Worrell's Turtles was 39% and 61% respectively.

Table 1 Trap Results for Reference Sites on Gregory River at Riversleigh

Habitat Type	Deep Water	Shallow Water
River Edge	WT= 44 GST = 0	WT = 30 GST = 0
Mid-river	WT = 9 GST = 0	WT = 2 GST = 0
Tufa Dam	WT = 2 GST = 0	WT = 0 GST= 0

WT = Worrell's Turtle *Emydura worrelli*
GST = Gulf Snapping Turtle *Elseya lavarackorum*
SST = Saw-shelled Turtle *Elseya latisternum*

b) Upper Gregory River and Ixion Creek

Twenty two Worrell's Turtles were collected from the upper Gregory River with most being caught in deep water sites along the edges of the river. Ixion Creek (a still-water habitat) contained fewer Worrell's Turtles but also contained a Saw-shelled Turtle *Elseya latisternum* (Table 2).

Table 2 Trap Results for Reference Sites on the Upper Gregory Drainage

Habitat Type	Deep Water	Shallow Water
River Edge	WT= 15 GST = 0	WT = 7 GST = 0
Still-water Creek	WT= 6 SST = 1 GST = 0	WT = 3 GST = 0

The Saw-shelled Turtle captured was a mature animal with a mid-dorsal groove in the carapace. It had a curved shell length of 25.0cm.

Snorkelling Survey of Reference Sites

a) Gregory River at Riversleigh

A total of five hours snorkelling time was spent in each habitat area. Forty seven turtles were seen of which 45 were Worrell's Turtles and two Gulf Snapping Turtles (Table 3). Worrell's Turtle was seen in almost equal abundance in shallow and deep water sites and were most commonly seen along the river's edge. The two Gulf Snapping Turtles seen were hand captured; both were sub-adult animals being 8.5 and 9.2cm long. One of these turtles was observed investigating a trap but would not go into it, eventually swimming away.

Worrell's Turtles were observed feeding on algae growing on the submerged roots on trees as well as foraging in soft sediment. While it was not possible to see what the turtles were harvesting from the sediment, it was thick with small gastropods, freshwater mussels and crustaceans. The floor of these areas were littered with opened mussel shells and yabbies claws.

Table 3 Results of Snorkelling Surveys at Reference Sites on the Middle Gregory River

Habitat Type	Deep Water	Shallow Water
River Edge	WT= 18 GST = 1	WT = 17 GST = 1
Mid-river	WT = 6 GST = 0	WT = 3 GST = 0
Tufa Dam	WT = 1 GST = 0	WT = 0 GST = 0

b) Lawn Hill Creek:

Twenty seven turtles were seen in Lawn Hill Creek of which 22 were Gulf Snapping Turtles (Table 4)(Figure 4). Of these most were seen around the tufa dams with large adult turtles often observed sitting beneath the overflow of the dams, in white water. Others were observed beneath the overhanging roots of fig trees that had become incorporated into the carbonate encrusting around the tufa dams.

Three Gulf Snapping Turtles were observed feeding of floating figs that had fallen from overhanging trees. One turtle was observed to make a lunge at a low branch in an effort to grasp a hanging fig with its mouth.

Fourteen adult Gulf Snapping Turtles were measured from Lawn Hill Creek; the average curved carapace length was 37.6 + 3.9cm and the shell sizes ranged from 23.8cm to 46.3cm.

Table 4 Results of Snorkelling Surveys at Lawn Hill Creek

Habitat Type	Deep Water	Shallow Water
River Edge	WT= 2 GST = 2	WT = 2 GST = 2
Tufa Dam	WT = 0 GST = 14	WT = 1 GST = 4

c) Upper Gregory River

A total of eleven Worrell's Turtles were seen in the Upper Gregory River (Table 5). Most of these were seen in deep water sites along the river's edge. In this section of the river's course there were few deep pools.

Table 5 Results of Snorkelling Surveys in the Upper Gregory Drainage

Habitat Type	Deep Water	Shallow Water
River Edge	WT= 9	WT = 2

Comparison of Trapping and Snorkelling Results

Turtle detection rates using trapping and snorkelling methods were compared. Detection rates were calculated as the ratio of the total number of turtles captured in a habitat compared to the time taken to detect them. Using this comparison an average time to detect each turtle using either method was determined. These calculations were only performed on data from the middle Gregory River sites (Table 6).

Table 6 Comparison of Snorkelling and Trapping Results

	Trapping			Snorkelling		
	Turtles Detected	Time (Hours)	Rate of Capture (time per turtle)	Turtles Detected	Total Time(hours)	Rate of Capture (time per turtle)
River Edge Deep	49	400	8.16	19	25	1.31
River Edge Shallow	34	400	11.76	18	25	1.38
Mid-river Deep	10	400	40.0	6	25	4.17
Mid-river Shallow	3	400	133.3	3	25	8.33
Tufa Dam Deep	2	400	200.0	1	25	25.0
Tufa Dam Shallow	0	400	-	0	25	-

Comparison of Bait Type in Traps:

Fish baits proved to be the most successful bait types for catching Worrell's Turtle although these turtles were captured in traps with each bait type (Table 7). Dried dog food was the least successful bait. None of the baits tested resulted in the capture of a Gulf Snapping Turtle.

Table 7 Comprison of Turtle Captures using Different Baits

Bait Type	Worrell's Turtle	Gulf Snapping Turtle
Sardines	44	0
Pilchards	36	0
Dog Biscuits	9	0
Carcass	23	0

DISCUSSION

Turtle Distribution and Abundance

Three turtle species were detected during this study. Of these only one, Worrell's Turtle *Emydura worrelli*, was found in all three study areas and occurred in a range of habitats (Tables 1-5). This species was only described in 1985 (Wells and Wellington), the type specimen being from the McArthur River drainage (Caranbirini Waterhole) in the Northern Territory. This species is presumed to be distributed throughout a number of drainage systems of the Gulf of Carpentaria ranging from the Katherine River in the west to the Saxby River in the south-east corner of the Gulf (Cann, 1998). Ecological information about this species is poor. Cann (1998) noted the apparent widespread distribution of the species and relates information about diet. Information about habitat use, movements and abundance records is absent.The present study indicates that Worrell's Turtle is a common turtle in large, slow flowing portions of rivers in the central Gulf region.

Gulf Snapping Turtles were found in the middle Gregory River near Riversleigh and in Lawn Hill Creek. They appear to be absent from the upper Gregory River. No adult turtles were found in the middle Gregory River and it may be significant that only sub-adult animals were found in this area (Figure 5). Large aggregations of adult turtles were present at Lawn Hill and were usually concentrated around the tufa dams. To date the known distribution of this species remains confined to the Gregory and Nicholson Rivers and Lawn Hill Creek, which occupy the central Gulf district. In 1998 adult Gulf Snapping Turtles were observed in the Roper River near Mataranka in the Northern Territory (A. White, pers. obs.) This suggests that these turtles may be much more widespread than currently believed.

The capture of a Saw-shelled turtle at Ixion Creek is notable. Cann (1998) suggested that this species was present in the Gregory River drainage and the capture of this animal confirms this prediction. Saw-shelled turtles are clearly uncommon or absent from the middle section of the river. As is the case elsewhere for this species, these turtles tend to be more prevalent in the headwaters of rivers rather than in the main body of the river (Cann,1998). The presence of this species in other sections of the Gregory River drainage has yet to be determined.

Turtle Behaviour

Although preliminary, this survey has provided valuable insights into the behaviour of some poorly known turtle species. Gulf Snapping Turtles are a trap-shy species. This behaviour seems to be consistent among all of the *Elseya dentata*-related turtles (Cann, 1998). Observations of Gulf Snapping Turtles around baited traps suggests that the turtles are unwilling to enter the enclosed neck of the trap. This suggest that standard barrel traps are inadequate to sample this species and open funnel traps may be more successful. Figs may also be a more successful bait in traps.

The observations of Gulf Snapping Turtles feeding on floating figs and trying to snatch figs from overhanging branches suggests that fruits may be an important component of their diet (and may also be a limiting factor in their distribution).

Observations on *Elseya dentata*-related turtles indicate that fruit and flower eating is a common activity. These turtles have been observed eating the flowers of *Melaleuca* and *Banksia* as well as fig fruits (Cann, 1998). Legler (1976) reports that these turtles eat leaves and bark as well as the fruits of figs, paperbarks and other stream-side plants. There are also several records of these turtles eating the fruits of *Pandanus* (Gray, 1872, Legler, 1976). Around Lawn Hill Creek, *Melaleuca, Pandanus* and *Ficus* are present with two species of figs *F. coronata* and *F. platypoda* being particularly common along the rocky shoreline. Figs were much less abundant along the middle Gregory River and appear to be even less common along the upper Gregory River.

The observation that Gulf Snapping Turtles appeared to congregate around the tufa dams suggests a potential feeding strategy. Water spilling over the tufa dams flows quickly for a short distance and carries floating plants material as far as the base of the tufa dam. Plant matter washed over is caught in the eddies beneath the tufa dam and remains trapped in this area until it sinks or is washed free. Turtles sitting under the tufa overflow are able to remain in sheltered positions and wait for floating food to be washed over the tufa rim.

Worrell's Turtle was observed to feed on algae growing from submerged tree roots and to forage in sediments for animal food. As these turtles readily accepted fish and meat baits (Table 10) this species is probably omnivorous. Legler (1976) reported that *Emydura* found in the Roper River ate *Pandanus* and other fruits and small molluscs. Worrell (1963) similarly reported these turtles eating snails and mussels. In previous trips to Riversleigh, Worrell's Turtles have been observed (A. White pers. obs.) feeding on a wallaby carcass that had been washed into the river.

Very little is known about the natural history of Saw-shelled turtles, despite their wide distribution. Worrell (1963) reported that these small turtles ate crayfish, water weeds and frogs. Legler (1982) found that animal and plant food made up about equal proportions of their diet. The hunting ability of these turtles has been noted (Cann,1998) as has their recently-recognised ability to ingest Cane Toads *Bufo marinus*. These turtles appear to be immune to the toxins in the toad's glands (Hamley and Georges 1985). Cane toads first reached the Riversleigh area in 1987 and have dispersed rapidly since then. They are well established along the drainage line and are present in large numbers at Ixion Creek (A. White, pers. obs.).

Comparison of Survey Methods

In general, trapping and snorkelling results complemented each other. Both types of survey method demonstrated the prevalence of Worrell's Turtles in the middle and upper Gregory River and both indicated the relative scarcity of Gulf Snapping Turtles in these areas. However, the relative efficiency of each method varied greatly (Table 6). Snorkelling surveys were much more efficient in terms of the numbers of animals caught per survey time. Not only were they more efficient, they detected trap-shy species. They have the disadvantage in that a larger survey team is required to carry out the survey and that some errors can arise through the double-counting of turtles, not being able to capture all of the animals sighted and potential disturbance of turtle activity in the river due to the presence of swimmers. Snorkelling surveys were most efficient in the middle Gregory River where the visibility is high and there are few underwater obstacles (Table 6).

Trapping methods were useful for detecting trappable species. In particular, traps require fewer survey staff, can better survey discrete habitats and are less likely to interfere with turtle activity patterns. Traps can also be used in murky water or in areas where large predators (i.e. salt water crocodiles) occur.

Observations of the reluctance of Gulf Snapping Turtles to enter the funnel neck of traps suggest that some modification of trap and bait design is required if Gulf Snapping Turtles are to be surveyed using this method. It is important that a successful trapping be

devised so that these turtles can be surveyed in the lower reaches of the Gregory River.

Bait Selection

None of the baits used were successful in trapping Gulf Snapping Turtles. As these animals appear to be highly frugivorous the range of baits tested in this preliminary study may have been inappropriate.

Worrell's Turtles responded to all of the baits tested with the fish baits being the most successful (Table 7). The reason for the success of the fish baits may be related to the aromatic oils that are released by the baits. Turtles were mostly observed swimming upstream to get to the fish-baited traps. As this species appears to be omnivorous the choice of baits may not be a critical factor in the success of their survey.

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Figure 1 Locations of Survey Sites in north-western Queensland

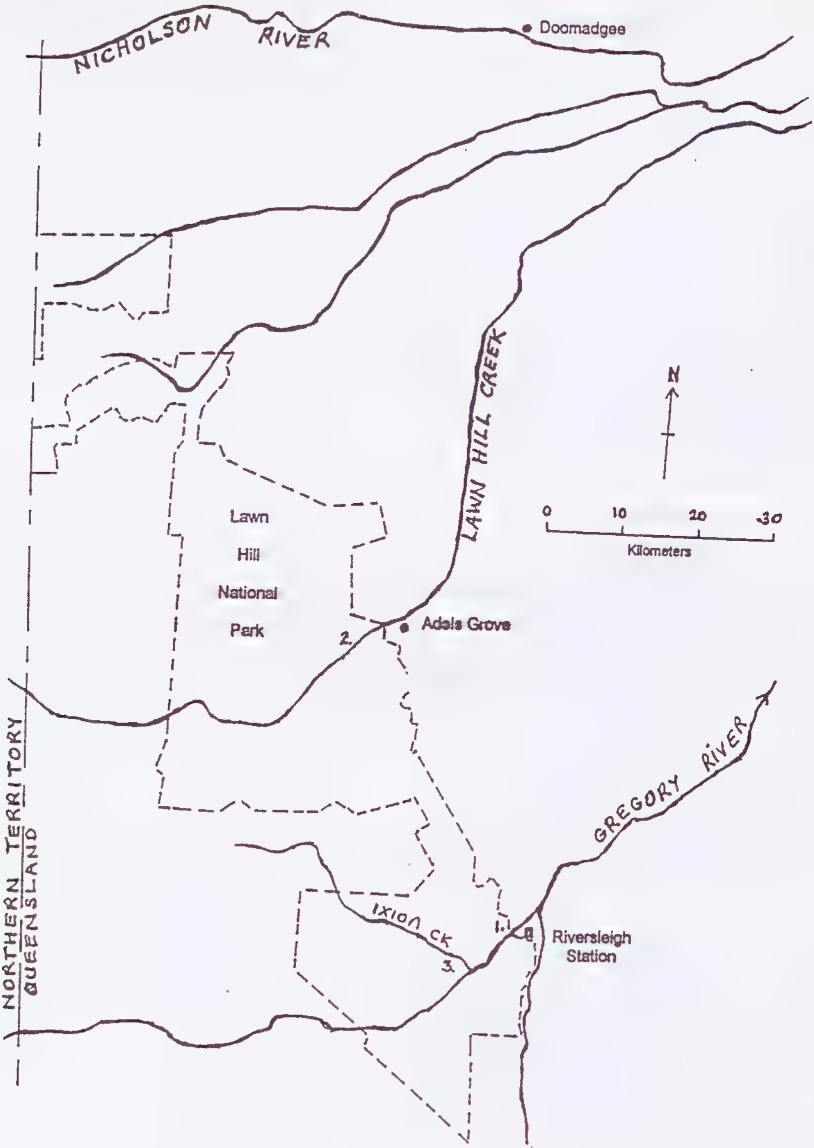

Figure 1

Location of Turtle Survey Sites

1. = Middle Gregory River
2. = Lawn Hill Creek
3. Ixion Creek and the Upper Gregory River

Figure 2 Setting turtle traps in Middle Gregory River

Figure 3 Hand captured turtles were passed to an assistant to be measured and processed

Figure 4 Large *Elseya lavarackorum*, Indirri Falls, Lawn Hill Creek.

Figure 5 Juvenile and adult *Elseya lavarackorum* from Lawn Hill Creek.

CAPTIVE MANAGEMENT AND REARING OF THE ROSEATE FROG, *GEOCRINIA ROSEA* AT MELBOURNE ZOO

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INTRODUCTION

The myobatrachid genus *Geocrinia* contains seven small-medium ground-dwelling frogs confined to the extreme south-west and south-east of mainland Australia, as well as Tasmania for *G. laevis* (Cogger, 1992). All species lay their eggs on land, on or beneath moist material, and, after completing early development, the tadpoles either remain there until rain stimulates their release, or they remain in the jelly mass (Tyler, 1994).

The Action Plan for Australian Frogs classifies 27 species as either Endangered or Vulnerable (Tyler, 1997). This includes two species in the genus *Geocrinia*, ie. *G. alba*, the White-bellied Frog (Endangered) and *G. vitellina*, the Orange-bellied Frog (Vulnerable). These are both listed as Endangered in Western Australia (Stanger *et al.*, 1998), and as Endangered (B1 & 2c) and Vulnerable (D2), respectively at the global level (IUCN, 1996). Both frogs have been the subject of co-ordinated attention, involving both state and federal Australian Government agencies, since 1990 and a Recovery Plan for both species was published in 1995 (Wardell-Johnson *et al.*, 1995).

Discussions during implementation of the first draft of the Recovery Plan led to consideration of using the related species, *G. rosea*, the Roseate Frog, to establish captive husbandry and breeding requirements, with the view to applying this knowledge to the two threatened species if that became necessary. Consequently, the University of Western Australia (UWA) and the Department of Conservation & Land Management (CALM) formally approached Melbourne Zoo in early 1994, with a request to develop captive husbandry and breeding techniques for *G. rosea*. The Zoo's proposal to undertake the project was accepted in June 1994 and the first group of frogs was transferred in July 1994.

The Roseate Frog is a small species, reaching 25-30mm in length, and is found in the far south-west corner of Western Australia, where it is confined to the wet karri forests (Cogger, 1992).

The primary goals of the captive program were to:

Establish and define the captive husbandry parameters essential for raising and maintaining frogs in the *G. rosea* complex.

Endeavour to investigate breeding cues for frogs in this genus and promote reproduction if possible.

MATERIALS & METHODS

Four different types of holding enclosures were used:

Two large outdoor custom-built glass tanks, each 1200mm long x 600mm wide x 600mm high (Fig. 1). These were naturally-landscaped and utilised "flow-to-waste" filtration, and were located in a secure off-limit area on the western wall of the Reptile House. From time to time, these had sub-surface water to a depth of 50-100mm to replicate the species' swamp habitat.

Four indoor glass tanks, each 470mm long x 550mm wide x 360mm high (Fig. 2). Each was equipped with a twin fluorescent light fitting containing a 20 watt "cool white" tube for illumination and a Compton 20 watt ultraviolet-emitting tube (BLB20). The substrate was an uneven mosaic of dense organic material (ie. loamy soil and palm peat) and sand. An under-substrate filtration system supplemented the above and free-flow circulation of the 20cm water.

One large, indoor glass tank, 1800mm long

Table 1. Arrival data for *G. rosea* at Melbourne Zoo on 14 July, 1994.

House ID	Sex	Snout-vent Length	Weight (g)
#1	1.0	21.5	1.1
#2	1.0	20.5	1.0
#3	0.0.1	14.0	0.3
#4	0.0.1	8.0	<0.1
#5	0.0.1	7.0	<0.1

x 460mm wide x 460mm high (Fig. 3). This was also fitted with a twin fluorescent light fitting containing similar lights to those above the other four indoor tanks. A trickle-filtration system fed water into the central section and the land areas at each end of the tank contained 8-10cm of palm peat. Dry leaf litter and small pieces of eucalyptus bark covered the land areas.

A series of plastic, commercially-available aquaria, each 230 x 230 x 350mm. These were furnished with an anaerobic "deep litter" flow-to-waste filtration system.

Ambient temperatures of 19-26°C were maintained in areas where the indoor enclosures were located.

Frogs were offered a diet of first and second instar Bush Crickets *(Teleogryllus oceanicus)*, Vestigial-winged Fruit Flies *(Drosophila melanogaster)* and Grass Flies (Family: Chloropidae). The Bush Crickets were dusted with Repcal, a vitamin-mineral supplement, and all insects were offered 3-4 times per week.

RESULTS

One group of two adult male frogs and three unsexed sub-adults were received at Melbourne Zoo on 14 July 1994, followed by two spawn clumps containing approximately 60 well-developed tadpoles on 7 December 1994.

Husbandry & Growth

The newly-arrived adult and sub-adult frogs were placed in one of the outdoor tanks. The adults, both males, were designated as #1 and #2, whilst the three unsexed individuals as #3, #4 and #5. The adults averaged 21mm snout-vent length and 1.05g, and the sub-adults 9mm and 0.2g on arrival (Table 1). Number three was subsequently found to be a female, while the other two sub-adults, #4 and #5, died during October 1994, approximately three months after arrival. Frogs 1 and 3 were still alive in late September 1996, but died in late October 1996, approximately 27 months after arriving at the Zoo.

In the 11 days following the arrival of the spawn clumps, 45 frogs successfully emerged from the jelly mass and were transferred to the small, plastic aquaria. The young frogs grew rapidly and were transferred to the second outdoor tank over the following six months. From a snout-vent length of 3mm at emergence, they grew to a mean snout-vent length of 16.2mm at 14 months and 22.9mm at 20 months (Table 2). Twenty seven of these were still alive after 15 months and 15 after 21 months. The last remaining frogs died 26-27 months after emergence.

Table 2: Sample growth rate of *G. rosea* at Melbourne Zoo (does not include data of original five animals which arrived 14 July, 1994).

Age (mths)	Sex ratio	Weight (g) (mean [range])	Snout-vent Length (mean [range])	No. of frogs measured
13.5	Unk.	0.45(0.21-0.71)	14.34(11.00-17.00)	16
15	8.9.1	0.63(0.23-1.10)	16.16(12.60-19.90)	18
18	3.5.0	0.86(0.40-1.30)	18.25(14.00-21.00)	8
20	2.2.0	1.55(1.35-1.78)	22.95(22.30-23.90)	4

In April 1996, the four indoor enclosures were established and groups of 6-7 similar-sized frogs were transferred into them from the outdoor tank. Each group comprised an approximately equal number of males and females.

Reproduction

Advertisement calls were first heard from the two original males, #1 and #2, in the outdoor tank on the morning of 31 October 1994, just over 15 weeks post-arrival. Calling had ceased by midday, although they could still be "called up" by their keeper throughout the afternoon. Despite regular calling during the following weeks, no spawn was laid during spring of 1994.

The 1995 season was similarly unproductive. The group at that time consisted of two adult males (#1 and #2), one adult female (#3) and approximately 30 young frogs.

Calls were next heard in April and June 1996, during the day at temperatures of 19-20°C. However, it was not until late July that female #3, in the outdoor tank, was found to be carrying numerous well-developed eggs, which were clearly visible through her abdomen wall. This frog weighed 3.56g at that time and measured 26mm (SVL), whilst Male #1 weighed 2.06g and measured 22mm (SVL). Other females, particularly in the indoor tanks, were also carrying developing eggs, which coincided with mature males commencing full "mating choruses" in early August. Males from both the indoor and outdoor groups continued their choruses during August, with peak calling activity occurring throughout September and into mid-October. One male was found calling from within a "nesting chamber" on 13 August and another unoccupied chamber was uncovered in an adjacent indoor tank. This latter chamber was spherical, approximately 16mm in diameter and had an opening in the top. Both chambers, although moist, had no standing water in the base and were located just above water level.

Group sizes and sex ratios were manipulated during this period of peak activity to promote spawning - groups ranged from two to five pairs together, as well as 1.3 (one male and three females) to 2.5. Frogs were also moved between the indoor and outdoor tanks. Females carrying eggs were also introduced to actively-calling males. In addition, temporary flooding of enclosures, consisting of allowing water to rise to the level of the substrate surface (approx. 100mm), and playing of self-recorded mating choruses provided greater flexibility in attempts to induce breeding behaviour.

The first spawning, on 25 August 1996, contained infertile eggs, which were dispersed in four small loose clumps around one of the indoor tanks. Four known spawnings occurred during spring 1996 (Table 3). The only fertile spawning occurred on 30 September, in another indoor tank containing three pairs of adult frogs which had emerged in late December 1994 and were, therefore, 22 months old. This spawn clump contained an estimated 25 eggs in a well-established burrow hidden beneath dry leaf litter and eucalyptus bark. The temperature of the egg mass was 22°C, whilst the surrounding soil had a pH of 6.6 and pH of the nearby water was 6.0. It was thought that the eggs may have been 2-3 days old, due to very small embryos being visible through the surrounding jelly. At least eight eggs contained partly developed tadpoles, but it was not possible to determine the status and condition of the other eggs without undue disturbance. The spawn and burrow site was immediately covered by a small plastic container with a mesh top to prevent the spawn mass being disturbed by frogs or food insects within the enclosure. However, the spawn was found to have been invaded by fungus on 4 October and had died.

DISCUSSION

A strong focus of the husbandry component of this project was to minimise disturbance of the frogs, to maximise their acclimatisation in

Table 3. Spawning and deposition sites for *G. rosea* at Melbourne Zoo.

Spawning (#)	Date (1996)	Enclosure (Fig.#)	No. of Eggs	Spawn	Spawning Site	Temp at Site(°C)
#1	25 Aug.	#2	21	4 loose clumps	Exposed & beneath leaf litter on land & at waters edge - clumps deposited over whole enclosure	22
#2	26 Aug.	#2	25	5 loose clumps	As for spawning #1	22
#3	30 Sep.	#2	Unk (-25)	1 confirmed clump	Beneath leaf litter on land in moist well-formed burrow(soil: 6.6pH; water: 6.0pH).	22
#4	3 Oct.	#3	Unk (-10)	1 loose clump	Beneath dry bark at waters edge (water: 8pH)	21-23

the Zoo's enclosures. Hence, while it is possible that more data could have been obtained, the Zoo's approach was that more intensive manipulation was something that could be undertaken once the husbandry and breeding protocols were fully determined, and the emphasis was on disturbing the frogs as little as possible, especially once breeding behaviour commenced. Indeed, the data presented in Table 2 are not a record of growth rates for the same individual frogs, but rather a sample of the growth of the total group. Measuring frogs was undertaken opportunistically, usually when they were moved from one enclosure to another.

It is not known whether the frogs received as adults died of old age or from disease, as no post-mortems were possible. These frogs are thought to live for up to six years (D. Driscoll, pers. comm.), so it is possible that they died of old age rather than disease. It was also not possible to post-mortem the young frogs, as they decomposed very quickly in the enclosures. However, there were no obvious signs of disease and, to that extent, it was felt that the environment was appropriate.

Very little information has been published on growth and breeding in *G. rosea* in the wild and nothing on its captive management. Indeed, there is nothing in the literature on captive management of any species of *Geocrinia*. The main objective of each enclosure design used at the Zoo was to create healthy stable environments for the frogs, and which required minimal keeper servicing; hence, minimal disturbance to the frogs also. The deep litter substrates had worked well with other species, as organic wastes are leaching down during flushing with fresh water and any nitrates trapped in the deep substrate are utilised by anaerobic bacteria in this humid environment.

The deep substrate also allowed the frogs to build their spawning burrows or depressions in soft, moisture-saturated soils and choose from a variety of potential spawning sites.

However, the number of eggs in the spawn clumps laid at the Zoo accords with the 26-32 eggs recorded by Main (1957 & 1968; in Tyler, 1994). It is interesting that the only clump of fertile eggs was laid in a single, well-defined mass, rather than the loosely scattered clumps or eggs in the other, infertile, spawn masses. The fertile spawn clump

was deposited in a small, well-established burrow beneath leaf litter and bark, similar to that recorded for *G. alba* and *G. vitellina* (Majors *et al.*, 1991). The eggs laid at Melbourne Zoo were not measured, but Main (1957) recorded egg diameter as 2.35mm.

The cause of the fungal invasion of the fertile eggs was unknown, although wild spawn masses have also been observed to suffer the same fate (S. Conroy, pers. comm.), and Malone (1985) found that embryonic and larval survivorship was less than 10% in *Philoria frosti*.

Despite the failure to achieve full captive reproduction, a number of achievements were attained:

Successful maintenance of direct development egg masses to emergence of young frogs.

Successful rearing of young frogs to adults (from emergence to 22 months of age) and recording of growth data.

Construction and successful trialing of three different enclosure designs (at least to the point of successfully maintaining frogs for over two years).

Development of practical husbandry methods.

Creation of conditions such that reproduction was achieved to the point of producing fertile spawn.

The Zoo's project ceased in November 1997, with the *Geocrinia* Recovery Team deciding to "focus its resources on refining the techniques for field translocations....as the primary mechanism for boosting population numbers of *G. alba* and *G. vitellina*" (K. Williams, pers. comm.).

ACKNOWLEDGEMENTS

Gerry Marantelli assisted in the maintenance of the frogs during the course of this project.

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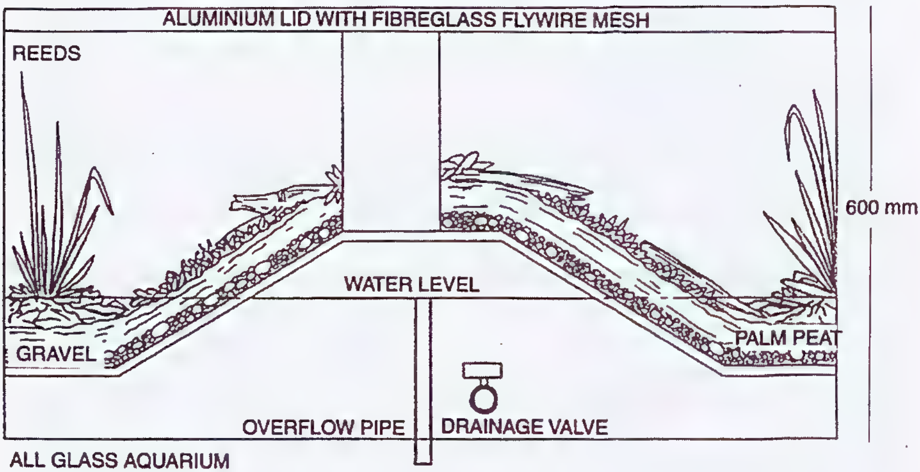
Figure 1.Outdoor holding enclosure for *Geocrinia rosea* at Melbourne Zoo

(a)Side View



(b)Plan View

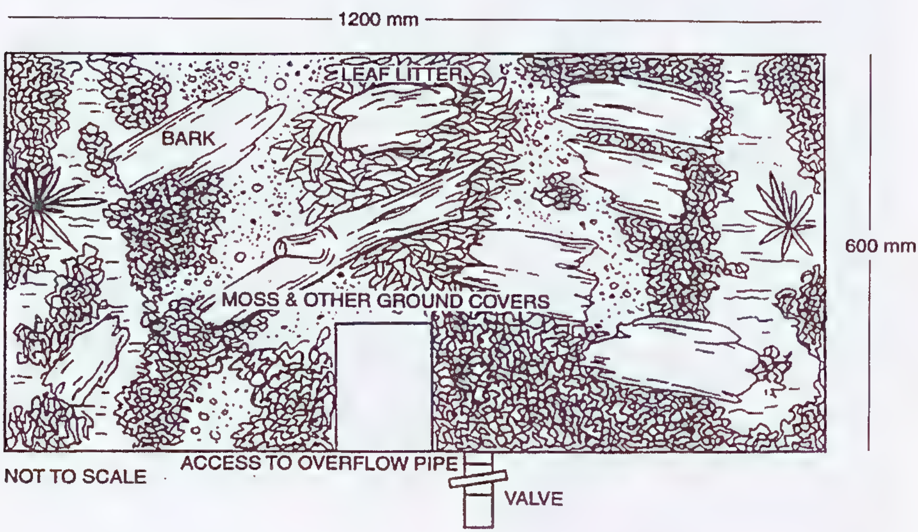


Figure 2. Indoor enclosure for *Geocrinia rosea* at Melbourne Zoo, using under-substrate filtration.

(a)Side View

(b)Plan View

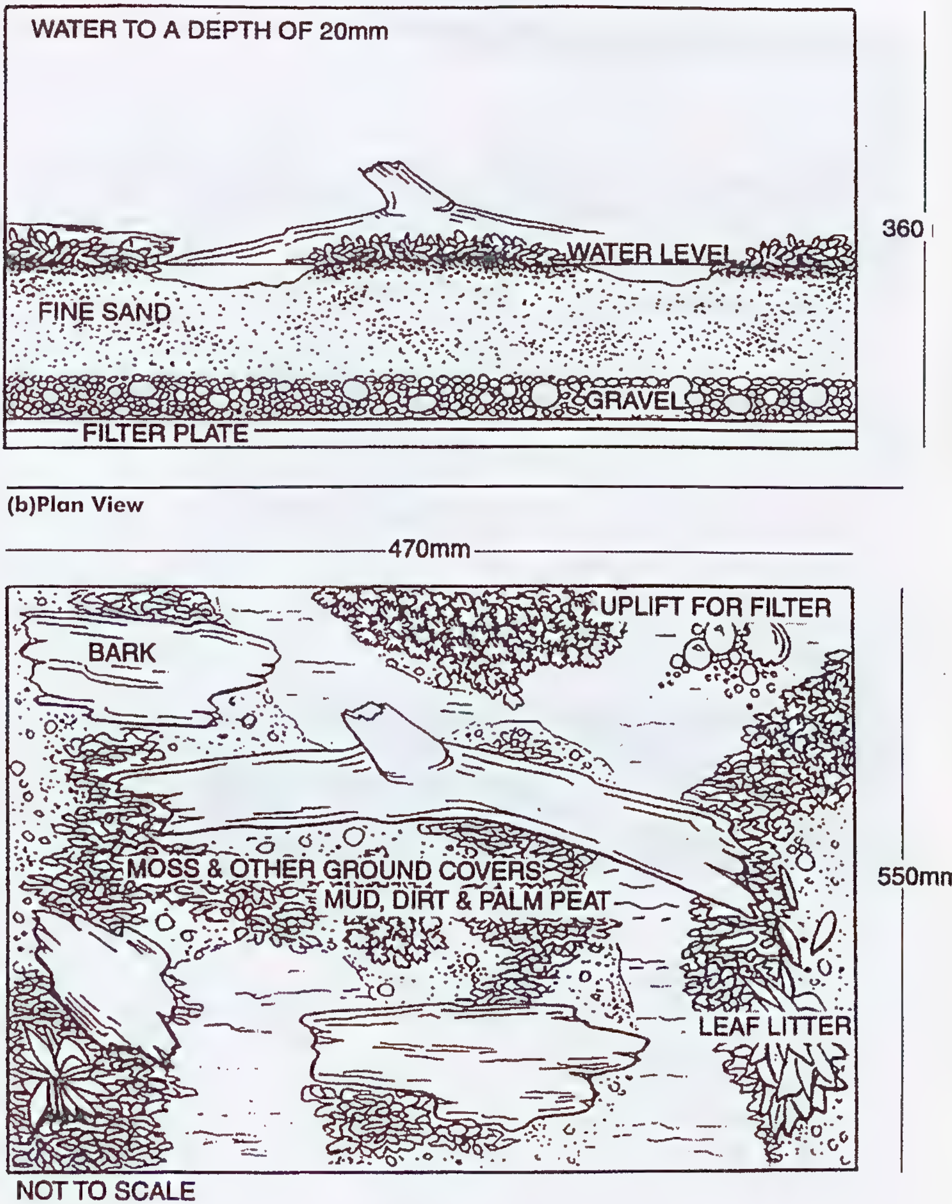
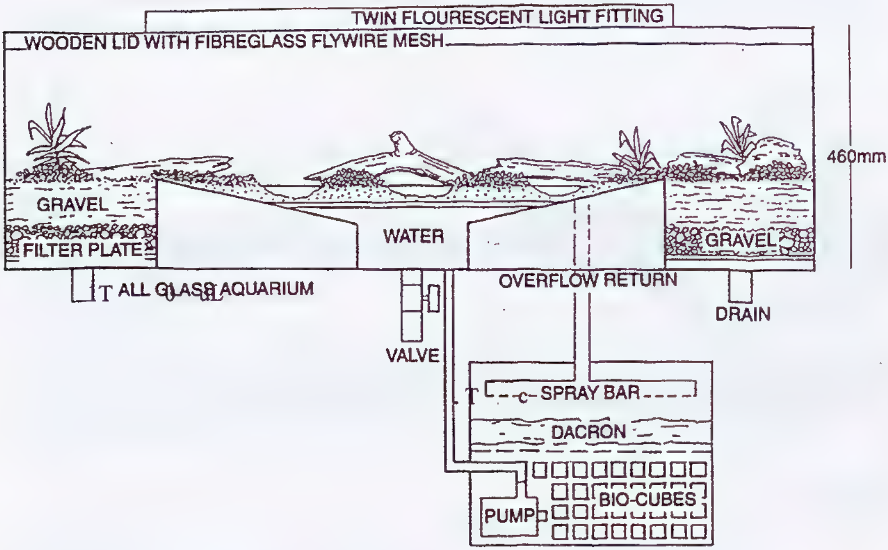
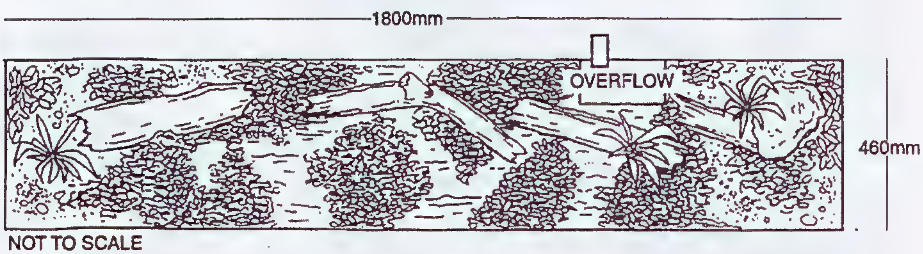


Figure 3. Indoor enclosure for *Geocrinia rosea* at Melbourne Zoo, using trickle filtration

(a) Side View



(b) Plan View



CAPTIVE BREEDING OF THE CAIMAN LIZARD, *DRACAENA GUIANENSIS*

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INTRODUCTION

Amazonian Caiman Lizards or Jacuruxi are among the most impressive saurians in the world (the generic name refers to a small dragon). With the total length over one metre, they are among the largest and most remarkable representatives of the family Teiidae. Caiman Lizards are well-known for their dietary specialisation, feeding on snails, and for their imposing crocodile-like appearance. However, knowledge of their natural history is surprisingly poor. A summary of recent knowledge on the morphology, distribution, habitat and natural history of Caiman Lizards is given by Avila-Pires (1995).

Caiman Lizards are internationally protected by CITES (Appendix II). They are very rarely exported as live animals. However, they are exploited to supply leather for the shoe trade (Sprackland 1992). They are only very rarely kept in captivity (Conant 1955, Werler 1970, Vanderhaege 1971). The latter two authors reported successful captive reproduction. However, in both cases, the eggs obtained for artificial incubation were deposited by recently imported females, apparently gravid when caught. The present paper gives information on the successful long-term keeping of Caiman Lizards and full reproduction in captive conditions. A preliminary report on the Caiman Lizards in Prague Zoo was given by Rehák (1995).

DESCRIPTION, DISTRIBUTION AND NATURAL HISTORY

Caiman Lizards are large, powerfully-built lizards, well adapted to semi-aquatic and semi-arboreal modes of life, and to snail-eating. The body is cylindrical, the tail compressed with a double dorsal crest, and representing about two-thirds of the total length. The eyes are positioned dorsolaterally, the lower eyelid thick and completely opaque, the tympanum superficial and easily visible. Dorsal scales bear large tubercles forming longitudinal rows. Limbs are well-developed, pentadactyle and fully-clawed.

Caiman Lizards show cryptic colouration. They are greenish, the dorsal surface and sides of the head with reddish areas, especially around the eyes. Colour photographs of Caiman Lizards are shown by Rehák (1995, 1996).

In spite to their name, the occurence of Caiman Lizards in the Guianas is doubtful (the type locality Cayenne, French Guiana, was corrected to Amapá, Brasil, north of Rio Araguari, by Hoogmooed and Lescure, 1975). Although Sprackland (1992) mentioned Caiman Lizards as common in much of South America, precise locality data are very few - Avila-Pires (1995) gives only 17 localities, including some that are uncertain. The known distribution of *D. guianensis* is along the Amazon valley eastward up to the Brasilian states Maranhao and Amapá westward up to Amazonian Colombia, Ecuador and Peru. Amazonian Caiman Lizards seem to be ecologically restricted to the courses of the main rivers of the Amazon basin.

Like locality records, observations on wild Caiman Lizards are very scant, and autecology and ethology of the species remain mostly unknown. *D. guianensis* is semi-aquatic and semi-arboreal. It is known to feed on snails - the shells are crushed with strong molariform teeth and shell fragments are expelled with the well-developed tongue. There are no field observations on reproduction apart from old (1897, 1902) observations by Goeldi (see Avila-Pires 1995) of two eggs (average length of 74.5 mm, average width 38.25 mm) found in a cavity in a termite nest.

Origin: Two males and one female of *D. guianensis* have been held at Prague Zoo since 22 August 1995. Subsequently, another male, kept separately, was imported to the Zoo. All animals originated from the vicinity of Iquitos, Peru.

Size, weight, growth:

The total lengths of the two original males at 10 January 1999 were 1108 mm (SVL = 403mm, tail 705mm) and 1015mm (420 + 595, tail regenerated). Their weights were 3085g and 3790g respectively. The female measured 968mm (325+407mm, tail tip incomplete), with a weight of 1373g. The growth of Caiman Lizards is rapid in younger animals. When imported, the males measured only 70-71cm and female 63cm. The increase in total length of the male with the complete tail was 30cm in the first year, but the later increase was slower - only 9cm in two following years.

Note on tail regeneration:

One of males suffered an injury to his tail after the importation. Consequently, he lost a large part of his tail. However, his tail completely regenerated within one year. So, in contrast to other large teiids like Tupinambis, Caiman Lizards have the ability to regenerate broken tails.

Sexual difference:

The female is smaller and, when compared to males, has a relativelly narrower head. The colour of the head in males is reddish, and in females greenish, with red colour restricted to areas around the eyes. Cloacal probes penetrated about 6-7cm into the hemipeneal pockets of males, while the female's tail base pockets are only about 2cm deep.

Note to the colouration:

Some physiological color change was observed - the colouration became darker at lower temperatures. Prior the shedding, the colouration is less vivid.

Food:

Caiman Lizards readily accept both living and dead (thawed frozen) Roman snails *(Helix pomatia)*. Usually, they are fed dead snails every second day, each lizard eating about 3-7 adult snails. Aquatic gastropods *(Ampullaria)* are also eaten, although Roman snails are prefered. Shells are crushed between the rear teeth, and their large fragments expelled by tongue movements while smaller fragments are swallowed (Figure 1). Smell plays the major role in food detection - offered snails elicit a typical tongue activity, both above and below water. The tongue is constantly flicked in and out, in the same manner as snakes and goannas, while the lizard moves about locating the snails. Our Caiman Lizards did not accept non-shelled gastropods *(Arion)*. Faeces are deposited exclusively in the water.

Enclosure:

The three Caiman Lizards shared the exhibit enclosure of 530 x 160 x 225cm. Half of the bottom is a water basin with a maximum depth of 60cm. The remaining part of the bottom is covered by a half-metre deep layer of peat/sand mixture. The rear wall consists of artificial rocks with large pockets for plants. Several stronger branches sit in the inner space of the enclosure.

Illumination is artificial, consisting of five halogen tubes (300 W) and four fluorescent tubes (20W), all shining for 12 hours a day, and two Osram Ultra Vitalux lamps (300 W) shining only 6 hours a day (1000-1600 hrs).

Temperature gradients in the terrarium are from 25 to 45°C. Even higher temperatures (up to 50°C) are on the heating plate on the bottom. Water temperature is about 27°C.

Daytime activity:

Caiman Lizards are diurnal. They spend the night sleeping in the wall pockets for plants, or in burrows they construct in the substrate. During the day, they spent most of their time on the branches and in the wall pockets,

basking near the Vitalux lamps (Figure 2). The greatest amount of movement (climbing, swimming, walking) is observed in the afternoon. They are good climbers, using their strongly clawed limbs and powerful tail, which is somewhat prehensile. Caiman Lizards are excellent swimmers and divers. They swim by undulation of the entire body and tail, especially the latter. The limbs are pressed against the body while the lizard is swimming. Before diving, they breathe out, and consequently they can spend a prolonged period under the water, walking or resting.

Defense:

When frightened, Caiman Lizards jump into the water and keep pressed to the bottom. When a potential threat (human hand) gets close, Caiman Lizards perform very fast lateral movements of the tail and head with open-mouthed jaws.

Social and sexual behavior:

Most of the year, the males are often together in close body contact, basking together and sleeping in the same cavity, while the female keeps away, remaining hidden for the most of the time.

We have never observed any antagonistic encounters or signs of aggression between the males. In contrast, both of the males are frequently observed to chase the female, who tries to escape in the water. The male then tries to return her to the shore. Such interactions are very dramatic - chasing is associated with the male biting the female's tail and limbs, sometimes resulting in a motionless posture on the ground or in the basin with the male holding the female in his jaws, with closed eyes, which can last for over an hour. Although some zoo visitors, when observing this posture, have reported that one lizard wants to kill the other, these encounters never caused any visible damage to female.

In spring 1997, the female's activity was very low. She spent most of the time in her burrow and stopped feeding. In September 1997, the males changed their behaviour, living in separate cavities. The female moved to one of the males, and he was tolerant to her at that time. Sometimes the male held the tail or foreleg of the female, but her response was friendly without any attempt to escape. During this period the female fed intensively. The other male ignored the couple. In November, the female left the first male and moved to the second male. They cohabited until egg deposition in January 1998. The egg deposition was followed by a three week period of intensive feeding by the female. Subsequently, the behaviour of the males and female returned to the usual pattern as described above.

No copulation was observed during the mating period. However, next autumn an interrupted copulation was observed. After chasing and biting, the male caught the female in the basin and held her forelimb firmly in his mouth while copulating in typical saurian posture with the tail base beneath the female's tail. After ten minutes, this behaviour was interrupted due to disturbance from zoo visitors.

Reproduction:

On 10 January 1998, the female dug out a cavity in one of plant pockets and laid four very large eggs (70-74 x 31-34mm, 43.0-47.50g). Measurements were taken within 24 hours of laying-before placing the eggs in the incubator. In comparison to published data, the size of the clutch was rather low (Werler, 1970, reported 7 eggs, Vanderhaege, 1971, reported 5 eggs). The eggs were white, dry and in mutual contact but not adherent. The female did not defend her clutch. Eggs were incubated on slightly damp vermiculite at 29-30°C. Two eggs, apparently infertile, were removed on 9 February and 18 March. The third egg died on 7 June, with a deformed embryo discovered inside. On 20 June, after 161 days of incubation a healthy lizard hatched from the final egg.

Juvenile:

The hatchling (total length 391mm, SVL 151mm, tail length 240mm, weight 122g)

resembled a small adult with the female type of head colouration. For its rearing, an enclosure 50 x 30 x 32cm was used, with a dish filled with water, branches, and lamp and temperature regime similar to the adults. Its first food, the small gastropod Cepea was taken at 19 days. In contrast, Vanderhaege (1971) reported two young refusing Cepea but accepting small aquatic gastropods. Later, the young started to accept chopped Roman snails.

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Figure 1 The fragments of the broken shell are expelled with the help of the tongue.

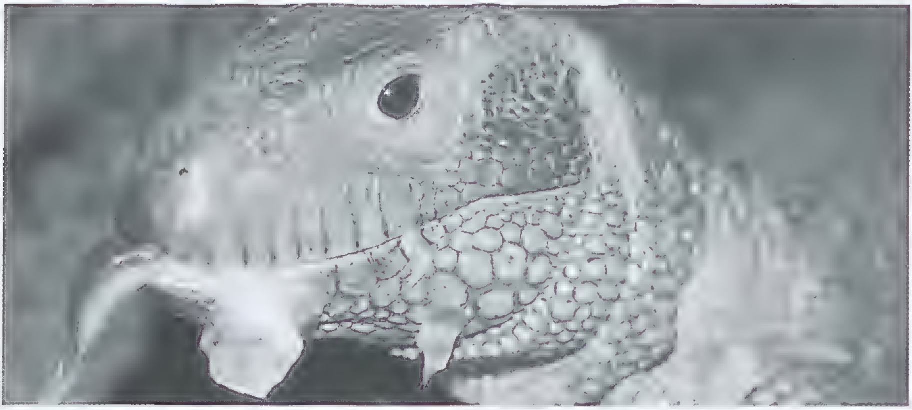
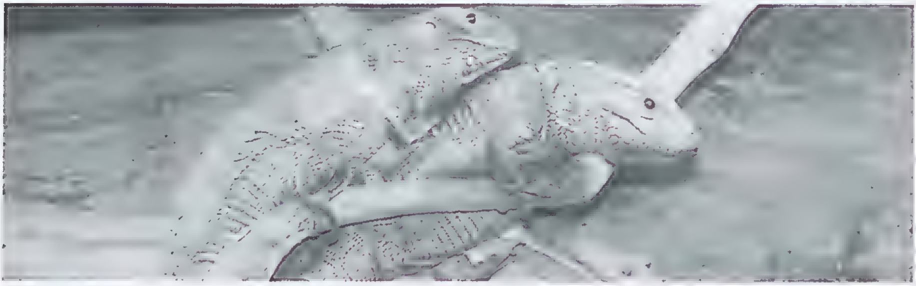


Figure 2 *Dracaena guianensis* basking near the Osram Ultra Vitalux lamps.



THE CONSERVATION OF THE GREEN AND GOLDEN BELL FROG *(LITORIA AUREA)* ON THE CENTRAL COAST OF NEW SOUTH WALES

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INTRODUCTION

Historically, the Green and Golden Bell Frog *(Litoria aurea)* was widely distributed and very abundant over much of eastern New South Wales and Victoria (Cogger 1992). Over the last three decades there has been a dramatic decline in the species to the extent that it has totally disappeared from vast areas of its former range (Mahony, 1996; White & Pyke 1996). There have been no records from high country localities for many years (Osborne et *al*, 1996). Those populations still existing in coastal regions are often isolated from each other by large areas from which the species has disappeared (White & Pyke, 1996).

The causes of these declines are probably many-fold but, in most cases, can be related to two main factors; habitat destruction or modification and introduced predators (White, 1995). Despite its ecological status as a mobile, colonising species, as an amphibian, *L. aurea* is still vulnerable to subtle changes to its environment (Pyke & White, 1996). These may take the form of pollutants or other water quality deterioration, wetland drainage or even minor changes in water tables. Colonising species will locate new habitats and reproduce before other competitive species arrive. Such habitats may take the form of ephemeral water bodies, which enable explosive breeders to take advantage of their brief availability. Human manipulation and alteration of such breeding sites may potentially disadvantage species like *L. aurea* in favour of other less transient species (White, 1995).

The introduced Mosquito Fish or Plague Minnow *(Gambusia holbrooki)* is a voracious predator of frog eggs and tadpoles (Morgan & Buttemer, 1996; Pyke & White, 1996; White 1995). Its resilience and fecundity, along with multiphased and repetitive introductions, have seen it become tremendously widespread in Australia, to the great detriment of both native fish and amphibians. As a coloniser, *L. aurea* probably located new breeding sites long before native fish established and, therefore, never developed adaptations to co-exist with fish predators. The sheer numbers and wide distribution of this fish have had a huge impact on *L. aurea* throughout its range. Other aspects such as disease and the effects of increased ultra-violet radiation (van de Martel & Buttemer, 1996) may have also played a role in the species' decline.

The suburbs of Sydney have long been one of the strongholds for this frog and its decline in this region has caused much concern and raised public awareness of the plight of this and other declining frogs. Luckily for the Green and Golden Bell Frog, Homebush, the site for Sydney's Olympic Stadium, proved to be one area where the species still clung to existence. Conservationists used this opportunity to highlight the frog's predicament and huge amounts of money have been spent accommodating them at the site. The spin-off from this public relations exercise has been an increase in interest in frogs in general, and this species in particular, in the surrounding areas.

Central Coast Populations

Like Sydney, the Central Coast of New South Wales was traditionally home to large, healthy populations of *L. aurea* which have now all but disappeared (White & Pyke, 1996; R. Wellington, pers. comm.) Surveys

carried out by the National Parks and Wildlife Service and Australian Museum several years ago indicated that the species was in a critical situation on the Central Coast. It appeared that a small, remnant population now remained, adjacent to the lagoon at North Avoca, surviving in suburban backyards. Specimens had been found in previous years, though their occurrence became less frequent over the years.

This triggered a proposal to undertake a salvage operation and the Australian Reptile Park offered its assistance to New South Wales National Parks and Wildlife Service and the *L. aurea* Recovery Team in trying to stem this loss in the region. A permit was applied for and obtained to collect up to twelve frogs from the North Avoca region. The aim of this collection would be to establish an insurance group of captive breeding frogs that may act as a source of stock for repopulating areas from which they had disappeared, if such an option was deemed necessary. Conserving the genetic material of this population is a high priority considering the small number of *L. aurea* existing between the Hawkesbury and Hunter Rivers (G. Pyke, pers. comm.)

A mailbox drop was carried out by Park staff utilising a flyer illustrating *L. aurea* and requesting help from the residents of the North Avoca area. As a result of this a pond was located in a suburban back yard, which was regularly inhabited by these frogs, and, during January-February 1998, six subadults and one adult frog were collected.

These frogs were housed in a large, naturalistic enclosure measuring 1.2 x 1.0 x 1.0 metres in size and receiving plenty of direct sunlight. This comprised a timber frame covered in an inner layer of aluminium insect mesh and an outer layer of 12mm square galvanised weld mesh, the latter providing extra security for the inhabitants. A 100mm strip of damp course material was attached to the inside bottom of the cage to stop frogs developing rostral abrasions on the coarse mesh surface. A large plastic tub embedded flush to the ground provided a water body and both natural and artificial refuges were installed. These comprised vegetation, logs and small sheets of marine plywood separated by 20mm spacers. The subadult frogs in particular appeared to thrive in this captive environment and doubled their mass in the 3-4 months before entering winter dormancy. However, on checking the enclosure in mid-August 1998, two frogs were found dead and a third was moribund. Pathology tests indicated the presence of chytrid fungus, a pathogen currently causing a great deal of concern for frog biologists. The remaining four frogs, however, continued to thrive and showed no ill effects of the fungus despite being housed in the same enclosure.

January 1998 produced a bell frog from a new Central Coast locality. Davistown, some 8 - 10 kilometres south of North Avoca, was an historical site for the species (J. Weigel pers. comm.) but no specimens had been located there for many years. The suburb is characterised by extensive saltmarsh areas. In response to the publicity campaign, residents located a Green and Golden Bell Frog in a private garden. Further investigation proved there were numerous specimens scattered throughout adjacent private blocks, raising hopes for the continued survival of the species in this area.

At this time, the Australian Reptile Park agreed to supervise a student from Newcastle University completing an Honours Degree in Environmental Science. Melanie Bannerman took on the Green and Golden Bell Frog project in an attempt to fully ascertain the status of the species in this region. Both Davistown and North Avoca were surveyed for the presence of frogs and suitable habitat. Funding was obtained from Gosford City Council to produce a colour flyer and an extensive mailbox drop was carried out at both Davistown and North Avoca. At this stage Davistown appeared to be the more viable population because of the number of frogs located. However, it rapidly became evident that few, if any, suitable freshwater breeding sites were pre-

sent in this area and, although the Australian Reptile Park obtained a permit to collect a number of tadpoles at Davistown, no successful breedings were observed in 1998 or 1999.

Another important development was the formation of a community group, 'Friends of the Green and Golden Bell Frog'. With representatives from New South Wales National Parks and Wildlife Service, Australian Museum, Gosford City Council, the Australian Reptile Park and numerous dedicated local residents, this group is a valuable contributor to conservation planning for the species in the local area. Regular meetings have highlighted areas needing particular attention such as community education, pond construction, additional planting at frog sites, etc. The group is also able to provide 'grass roots' proposals to the species recovery team.

Meanwhile, continuing surveys at North Avoca resulted in the discovery of probably the only current breeding site for the species on the Central Coast. This site consists of one pond, approximately 30 metres x 30 metres at full capacity, which is physically separated from the North Avoca lagoon by a narrow levee bank. This bank which, at its widest point is no more than three metres across, keeps the saline, *Gambusia* infested waters of the lagoon away from the *L. aurea* breeding site. Over the 1998-1999 season regular surveys by the Australian Museum, members of the community group and volunteers, recorded successful breeding with large numbers of metamorphs emerging from this pond. Brisbane Water Gosford Lagoon Catchment Management Committee provided funding for micro chips and a mark- recapture program was initiated by Dr Graham Pyke in late 1998 and will continue for another two breeding seasons. To date, the population is estimated at around 300 individuals (G. Pyke pers. comm). The Australian Reptile Park also collected some twenty tadpoles and these now form the nucleus of a captive breeding group at the Park, separate from the four potentially chytrid-positive adults collected previously, which continue to thrive without further visible ill-effects. It is hoped that these new frogs may be large enough to reproduce during the 1999-2000 breeding season.

The Central Coast experienced heavy rainfall during February 1999 to the extent that the North Avoca lagoon water levels rose and inundated the *L. aurea* pond, swamping the remaining tadpoles with brackish water and predatory *Gambusia*. Gosford City Council manually controls the levels in the lagoon by opening the sand bar at the mouth if surrounding dwellings are under threat. The decision was taken to carry out this task in February 1999 to reduce the lagoon levels. This event indicated that the water in the breeding pond was connected to the main lagoon water table as reducing lagoon levels also drained the breeding pond. The Australian Reptile Park, National Parks & Wildlife Service and local residents in concert, undertook a brief rescue mission to salvage a number of tadpoles from the pond. These were transferred to children's paddling pools in neighbouring gardens where they were allowed to develop and metamorphose naturally and move off into the surrounding area otherwise unassisted.

CURRENT SITUATION

The status of the Green and Golden Bell Frog on the Central Coast is still somewhat in the balance. The situation is much healthier with the discovery of a breeding site, though, clearly a great deal of in-situ management of the site will be required by all parties to ensure regular, successful reproduction and recruitment. Recommendations have already been made to Gosford City Council by New South Wales National Parks & Wildlife Service to amend lagoon opening policy and notification procedures (R. Wellington pers. comm.) Manipulation of lagoon and pond water levels are essential in maintaining the integrity of the breeding pond. After inundation it would also be necessary to ensure the pond is allowed to dry out totally to eradicate any *Gambusia* that may be present. Other

steps may be deemed necessary to further protect this valuable resource. Bolstering of the levee bank may assist in maintaining the separation of the breeding pond from the main lagoon. Reliance on a single breeding pond to ensure the continued existence of the species on the Central Coast is obviously a dangerous policy. The construction of further breeding ponds, which are not under water table influences, around the North Avoca lagoon has been suggested in the hope of providing an extra safety net to guarantee safe breeding sites for the species. The Friends community group and Gosford City Council are currently examining this possibility. The National Parks & Wildlife Service have also initiated habitat creation as part of the Saltwater Creek rehabilitation works (R. Wellington pers. comm).

The status of the Davistown population is somewhat uncertain. Further intensive surveying is required to ascertain if any suitable breeding sites are present in the area. If none are located, serious consideration must be given to the construction of several breeding sites. Such projects will require both funding and community support to be successful. Establishing an insurance captive breeding group of Davistown specimens at the Australian Reptile Park should also be a high priority. Enhancement of areas as potential breeding sites near historic *L. aurea* localities are important considerations with valuable education and public awareness spinoffs.

If the Green and Golden Bell Frog is to survive at any location in New South Wales it will clearly require a great deal of continued assistance and management. Removal of the causal factors contributing to its decline throughout its range is not a viable option. However, micromanagement of specific sites to control the relevant factors is imperative to ensure long- term survival of current discrete populations. Other options, such as translocation or habitat creation and natural colonisation, must also be considered as potentially important tools in stabilising and expanding the representation of this frog, both on the Central Coast and other regions.

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ARE SYMPATRIC MONITORS SPEAKING WITH FORKED TONGUES? SYMPATRY AND TONGUE COLOUR IN SIBLING SPECIES OF MONITOR LIZARDS

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ABSTRACT

The taxonomy of varanid lizards has represented a dynamic area of study for herpetologists. When cryptic or semi-cryptic species are involved, an important question to be addressed is how the monitor lizards themselves deal with their taxonomy. This study reports on morphological findings that demonstrate how similar and sympatric species show diversity of phenotypes that are otherwise atypical or extreme for each species concerned. In comparing distributions and phenotypes of varanids from New Guinea and Africa, distinct phenotypic plasticity is observed in various features of varanid anatomy, particularly for tongue color. Two hypotheses are presented that are supported by these observations: first, that as the number of species in an area increases, the number of character states for a feature increases; and second, the wide variation of coloration supports the hypothesis that varanids are strongly visually-oriented, and species-specific recognition may be largely a function of color and pattern.

INTRODUCTION

I have been engaged in studying variation in monitor lizards for much of the past two decades. Considerable effort was spent on trying to understand the boundaries between similar species. Many evolutionary zoologists have found this group to be particularly rewarding to study from a variety of micro- and macromorphological perspectives. These studies have included karyology (Fritz and Fritz, 1991; King and King, 1975), protein electrophoresis (Holmes *et al.*, 1975), immunology (King *et al.*, 1991; Baverstock *et al.*, 1993), paleontology (Lee, 1997; Sprackland, 1991), hemipenial morphology (Böhme, 1988, 1991; Böhme *et al.*, 1994; Branch, 1982; Ziegler, 1994), internal anatomy (Becker, 1991), and external anatomy (Gaulke, 1989, 1991; Sprackland, 1991, 1993a, 1993b, 1997). Coupled with these projects have been the additions of valuable data regarding ecology, behaviour, and physiology that increasingly enhance our understanding of relationships and patterns of evolution.

Pursuing this line of investigation, to see and comprehend species boundaries and speciation processes, led me to another question: if zoologists have trouble discerning among cryptic sympatric species, how do the lizards recognize each other? Many of the cryptic or morphologically similar sympatric and parapatric taxa have only recently been recognized for what they are, e.g. distinct species. Branch (1982) first separated the African *Varanus albigularis* from *V. exanthematicus*, and left the subspecies formerly allied with the latter to *V. albigularis*. In that same study, he separated *Varanus timorensis* from the rest of the subgenus *Odatria*. Storr (1980) recognized specific differences between Australia's *Varanus gouldii* and his new species *V. panoptes*. Böhme *et al.* (1994) and Sprackland (1995, 1997) distinguished five taxa from the Indo-Australian *Varanus indicus*-complex that had hitherto been unrecognized or relegated as subspecies of *V. indicus**[1]. If these monitors have confused herpetologists, then how do the lizards distinguish themselves from cryptic species with which they are sympatric?

[1] I have assigned the lizards belonging to the mangrove monitor assemblage a metataxon elsewhere (Sprackland 1995 and in press), hence the inclusion of the asterisk in the binomial.

Auffenberg (1988) noted that the color of the tongue differed among some varanid species, and alluded that such a character, if fixed, might be of taxonomic importance. Sprackland (1992) used tongue color to partially distinguish between species of the North American varanoid *Heloderma*, and Böhme *et al.* (1994) and Sprackland (1993, 1994, 1995, 1997) have used the feature as diagnostic in distinguishing among some varanid species. This study reports on varanid taxonomy from the lizard's viewpoint. I have examined sympatric monitor lizards from Australia, Africa and New Guinea, and present my findings on conspicuous character displacement and its range of variation within a species for the latter two locations.

MATERIALS AND METHODS

Through the combined resources of preserved museum and a large number of live specimens I was able to examine over 1500 specimens (a complete list of which is found in Sprackland 1995) within the mangrove monitor complex, along with nearly as many African and Australian specimens. For museum specimens, tongue colour was recorded as accurately as possible, but this was often limited to "dark" or "light" due to preservation. A list of institutions and individuals who provided materials for this study is given in the acknowledgements.

RESULTS

The tongue of a monitor may be (in increasing order of occurrence among species) yellow, dark bluish-purple, or pink (Table 1). Sometimes the diagnostic colour may be present only on the anterior portion of the tongue, including both tines and a short area more proximal to the base (i.e., *Varanus yuwonoi*). In such cases, tongue colour is based on the anterior tongue colour. In preserved specimens, yellow tongue color may turn gray, hence Böhme *et al.* (1994) referring to the tongue of *Varanus doreanus* as gray.

Two species complexes were studied. The first and more detailed study involved five species of the *Varanus indicus*-complex of Indo-australia (Böhme *et al.*, 1994; Sprackland, 1995, 1997), though I've added data for three species described since 1995 in Table 1. The second group included the African monitors exclusive of *V. griseus*. I present the results separately by geography.

INDO-AUSTRALIAN MONITORS

At the time of this study five species of mangrove monitors were recognized: *Varanus doreanus* (Meyer, 1874), *V. finschi* Böhme, Horn & Ziegler, 1994 (described as a subspecies of *V. doreanus*, but elevated by Sprackland [1997]), *V. indicus** (Daudin, 1802) recognized as a metaspecies by Sprackland (1995, 1997), *V. jobiensis* Ahl, 1932, and *V. spinulosus* Mertens, 1941. Subsequent to my research, *Varanus yuwonoi* (Harvey and Barker, 1997), *Varanus melinus* (Böhme and Ziegler, 1998) and *Varanus caerulivirens* (Böhme, Ziegler and Philipp, 1999) have been described, and tongue colour information for these taxa are presented in Table 1.

*Varanus indicus** has a dark purple tongue, a unique condition for described mangrove monitors. However, the percentage of the tongue surface so colored varies among populations, with those from Halmahera and western New Guinea (representing the far western distribution for the species) having nearly uniformly dark tongues. Lizards taken in eastern New Guinea and the Solomon Islands have only the anterior one-third to one-half (always including the entirety of the tines) dark, the posterior portions pink (though a darker pink than seen in either *V. melinus* or *V. spinulosus*). *V. indicus** is further unique in being the only taxon sympatric with all other mangrove monitor species, excepting perhaps only *V. melinus*, for which data are still lacking.

Varanus doreanus is an unusual varanid in having a pale yellow tongue, known elsewhere in only three other monitor species (Table 1), one of which, *Varanus yuwonoi*, has a distinctly dark posterior tongue. In fact, the tongues of *V. doreanus* and *V. yuwonoi* are quite similar; so far as known, these species are quite allopatric. In both the tines are universally yellow, as is a

short region posterior to them, but the tongue typically yields to pink coloring for most of its length (Harvey and Barker, 1998; Sprackland, 1997). The remaining species possess pink tongues.

The pattern of distribution of tongue color is interesting because:

Wherever two species are sympatric, one has a purple tongue (*V. indicus**), and the other a pink tongue. Within the Solomon Islands, *V. spinulosus* and a recently discovered but unnamed taxon/color morph have pale pink tongues, with no indication of any darker coloring. New Britain endemic *V. finschi* is also pink-tongued, and is sympatric only with *V. indicus**. The sympatry of *V. indicus** and *V. yuwonoi* on Halmahera presents an interesting case, as the latter has a yellow tongue tip, but a pink posterior tongue.

On New Guinea, *V. indicus** and the yellow-tongued *V. doreanus* are broadly sympatric, particularly among the riparian lowland habitats. A third species, *V. jobiensis*, is broadly sympatric with these, particularly in Irian Jaya (=western New Guinea). *V. jobiensis* prefers drier habitats, ranges further from water, and apparently prefers higher elevations. There are no known localities where *V. jobiensis* is sympatric solely with *V. doreanus*. The fact that where three mangrove monitors are sympatric they all have differently colored tongues suggests to me that tongue color is useful in determining conspecific recognition among the lizards.

AFRICAN MONITORS

The African varanids represent a well-defined clade within the Varanidae, and include *Varanus niloticus, V. ornatus, V. albigularis,* and *V. exanthematicus*. The taxonomy of African varanids has been unstable (Baverstock *et al.*, 1993; Branch, 1982; Holmes *et al.*, 1975; Mertens, 1942). For a variety of morphological and ecotypic reasons, I regard *V. albigularis* as monotypic (Bayless and Sprackland, in press.). *V. niloticus, V. exanthematicus*, and all "subspecies" of *V. albigularis* have dark blue or purple tongues. Additionally, even where these taxa are sympatric, they prefer different habitats, so that interspecific encounters are rare. Only *V. exanthematicus* and *V. albigularis* are easily confused with each other, though they differ in coloration, pattern, habitat preference, and size. The former, a bland grayish lizard with indistinct markings and a nostril well anterior of the orbit, lives in dry savannas and forest edges. *V. albigularis* has a much wider range, and though it exploits savannas, prefers areas near permanent water. *V. albigularis* is characterized by its distinct spotted pattern, black throat (prominent in juveniles, but faded in many adults), and the nostril almost in contact with the orbit.

TABLE 1. Tongue colors documented from living varanoid lizards.

Dark Blue/ Purple		
Heloderma suspectum		
Varanus:	albigularis	salvator
	exanthematicus	spenceri
	indicus*	varius (part)
	giganteus	yemenensis
	niloticus	
Yellow		
Varanus:	doreanus	komodoensis
	varius (part)	yuwonoi
Pink		
Heloderma horridum		
Lanthanotus borneensis		
Varanus:	acanthurus	olivaceus
	beccarii	ornatus
	bengalensis	prasinus
	bogerti	primordius
	caerulivirens	rudicollis
	caudolineatus	salvadorii
	dumerilii	spinulosus
	finschi	storri
	glebopalma	telenesetes
	jobiensis	teriae
	mertensi	timorensis
	melinus	tristis

Varanus niloticus is a purple-tongued and widely distributed lizard, while the more distributionally restricted, brighter-colored, pink tongued *V. ornatus* was long considered a subspecies of *niloticus*. Found in forests, especially near standing water in west coastal Africa, *V. ornatus* differs markedly in ecology and coloration to warrant recognition as a full species, *Varanus ornatus* (Daudin, 1803).

Varanus exanthematicus has a range across middle Africa, extending from Senegal (*terra typica*) to Egypt, though populations in Egypt and Sudan are possibly relictual; I have found no reliable records for the species in the broad area of desert between Lake Chad and the western Nile region of Sudan. There lives in Sudan, Kenya, Ethiopia, and surrounding eastern areas a yellowish (vs. gray) monitor resembling *V. exanthematicus*, but having smaller scales and pink tongues (pers. obs.). This taxon is sympatric with *V. albigularis* and *V. niloticus* (=*V. niloticus*), but I have been unable to corroborate its sympatry with *V. exanthematicus*. Bayless and Sprackland (in press) believe that this population represents *Varanus ocellatus* Heyden, 1827.

DISCUSSION

Wherever morphologically similar goannas are sympatric, each taxon possesses a different tongue colour. I first noticed this fact when redescribing *Varanus spinulosus* from the Solomon Islands (Sprackland, 1993, 1994). In 1991 I was able to examine freshly collected specimens, and noted the pale pink tongue was in stark contrast to the purple-tipped tongue of the sympatric *V. indicus**.

I subsequently examined lizards of the mangrove monitor complex, noting significant pattern variation fell into loosely defined geographic areas. By observing live specimens, I was able to detect the fact that tongue coloration was useful in distinguishing specimens from different areas. Sadly, one of the most unusual and highly diagnostic characters for the identification of mangrove monitor taxa is color (Sprackland, 1995, 1997), though the intense blue hues seen on the tails of some *Varanus doreanus, V. yuwonoi* and *V. jobiensis* fade to pale gray when specimens are preserved. This artifact of preservation explains why so distinct a species as *V. doreanus* went largely unrecognized from 1874, when it was first named, until 1994, when it was recognized for what it is (Böhme *et al.*, 1994).

I found no evidence of tongue color variation among Australian monitors of the subgenus *Odatria*, nor is it present between morphologically distinct sympatric taxa elsewhere (i.e., *Varanus dumerilii* and *V. rudicollis*). For members of *Odatria*, it is possible that habitat distribution and habits keep sympatric taxa functionally separated, so that visual cues to intraspecific recognition are less crucial; alternatively, perhaps they have simply not had time or selection pressure to evolve such variation. Given the overall similarity between and among the *Odatria* group, it seems probably that the dramatic (even if possibly genetically minor) shift in tongue pigmentation simply has not had time to evolve. Field studies of many sympatric taxa have strongly demonstrated that there is frequent and distinct habitat partitioning among these lizards, which in turn may negate selective pressures to alter tongue colour.

In the African and Indo-Australian species studied, though they occupy greatly different habitats, several features were shared that lend support to a hypothesis of natural selection directing evolution of a variety of tongue colors:

In both regions, there are localities that have at least three morphologically and ecologically similar taxa in broad regions of sympatry. In such places, tongue colour variation may be a visual cue for species identification. The lack of a third tongue color in Africa suggests to me that even where three taxa are sympatric, they may actually be separated by microhabitat exclusion or seasonal activity, making only two tongue colours necessary.

In both regions the species involved are generally wide-ranging. Tongue colour also seems correlated with range: Those species

with the largest distributions have the most common (for *Varanus*) tongue colour, dark blue/purple. Peripherally occurring species have the next most common tongue colour, pink. The third (rare) tongue colour is seen only where three ecologically very similar taxa have broad areas of sympatry. So far, the only place known that meets this criterion is central Irian Jaya, New Guinea.

From these data, I hypothesize that as the number of related species in an area increases, the number of character states per character tends to increase, particularly in features of colour and pattern. Among the mangrove monitors, for example, I have documented at least four very distinct patterns of tail markings, and eight patterns of temporal/facial markings (Sprackland, 1995). While these patterns are not always species-specific (especially where *Varanus indicus** is concerned), they have so far been seen to be population-specific.

Monitor lizards possess eyes with both rods and cones, indicative of acute colour vision. They are also diurnally active predators for whom visual acuity is important. The variety of colour and pattern seen among related varanids supports the following hypotheses: 1) varanids are indeed animals with good colour vision and visual acuity (i.e., the ability to see something as small and fleetingly extruded as a tongue) and
2) natural selection has acted on a distinctive "flag" used by the lizards which allows inter- and intraspecific recognition at some distance, presumably a greater distance than pheromonal cues would allow. The sympatric occurrence of two or more closely related varanid species is more common than not in most areas of varanid distribution. It would be interesting to see how specimens would respond to models of different colours.

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A THIRTY YEAR HISTORY OF MELBOURNE ZOO'S HERP DEPARTMENT

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ABSTRACT

Melbourne Zoo's current Reptile House was officially opened on 22 October 1969. Since that time, 82 species of reptiles and amphibians have been bred, many species having been bred on more than one occasion. Significant successes include Freshwater Crocodiles, Arafuran File Snakes and Striped Legless Lizards - all world firsts. Through an agreement with the Department of Conservation & Natural Resources in 1987, dedicated holding facilities were constructed for confiscated reptiles, as well as a staff office and additional insect breeding rooms. To deliver the Zoo's commitment to frogs, "World of Frogs" was opened in 1993, on the main building's north wall and the Section's name was changed to "Herpetofauna" to more accurately reflect its breadth of operations. Over the past 11 years, off-limit facilities in the House have been progressively upgraded to achieve more effective holding of reptiles in better conditions for the reptiles and the staff looking after them. Commencing in the late 1980's, the Section now has direct involvement in a range of national and international conservation and management programs. These include Broad-headed Snakes *(Hoplocephalus bungaroides)*, Barred Frogs *(Mixophyes spp.)*, Frilled Lizards *(Chlamydosaurus kingii)*, Fijian Banded Iguanas *(Brachylophus fasciatus)*, Aldabra Giant Tortoises *(Aldabrachelys gigantea)* and Reticulated Gila Monsters *(Heloderma suspectum suspectum)*; and *in situ* links for Philippine Crocodiles *(Crocodylus mindorensis)*, Striped Legless Lizards *(Delma impar)*, Romer's Tree Frogs *(Philautus romeri)* and South East Asian Freshwater Turtles. The Section also plays key roles in the Australasian zoo region's Reptile Taxon Advisory Group, which co-ordinates management of reptiles in Australian and New Zealand zoos.

INTRODUCTION

Melbourne Zoo has displayed reptiles for many years - extracts from Board Reports note the death of a Boa Constrictor in 1878 and the then Reptile House was destroyed by fire in May 1882 (de Courcy, 1995). The new Australian Section, including a Reptile House, was opened in November 1934 (de Courcy, 1995). In the mid 1960s, the Zoo embarked on a new Masterplan, involving the development of more naturalistic exhibits and including the conversion of some of the existing structures. Among the new developments was a Reptile House, although the decision was taken to implement this via conversion of a large, disused storage building.

This building had started life as a large wire aviary, which was constructed in the 1930s and seen various subsequent uses as an experimental nocturnal house, a storage centre and as a holding facility for macaques imported for vaccine development by the Commonwealth Serum Laboratories. The building was gutted in early 1968 and construction of the exhibits and internal holding areas commenced. Although the major construction was undertaken by external contractors, the design and landscaping of the exhibits was primarily the work of the Curator at the time, Roy Dunn. It is a testament to his skill that the exhibits have withstood the test of time and, minor repairs notwithstanding, are as relevant and visually appealing today as they were when the building was officially opened almost 30 years ago (Fig. 1). Key features underpinning this success are the clear panels in the roof, which allow much natural light through to support the live plants, and the front servicing of the displays. The latter aspect allows large branches, etc. to be positioned in the exhibits and for the staff, whilst landscaping, to view the exhibit as it is by visitors, rather than having to access the exhibit

through a small door located in the rear wall of the exhibit, as is still the case with many new reptile complexes.

Animals for the expanded collection were gathered over the two years preceding opening and comprised a number of specimens from the previous display, as well as major importations from El Paso Zoo, Texas, and Los Angeles Zoo, California. The "new" Reptile House was officially opened on 22 October 1969, by Sir Arthur Rylah, the Chief Secretary for Victoria, with the star attraction being a large male D'Albertis Python *(Liasis albertisii)*. Since that time the House itself has grown and been modified, and the collection and its management has evolved in keeping with the changing directions of zoos over the past three decades (Fig. 2).

CAPTIVE BREEDING

A major thrust in the early years of the Reptile Department, as it was then called, was breeding. Over the period of 1969 to the mid-1980s, great store was placed on the number of species bred and young raised. Indeed, this was a global phenomenon, and one only has to look in the available reptile magazines of those times, including conference proceedings, to see the emphasis placed on this feature of reptile management. There were exceptions of course, such as Bill Conway's "How to exhibit a bullfrog" and Joe Lazlo's pioneering work on use of lighting for captive reptiles in zoos (Conway, 1973; Lazlo, 1969), but it was later in this period before consideration of these wider management issues became more the norm.

The first four years were relatively quiet, with the first breeding (defined in this paper as captive mating followed by eggs or young) in the new building occurring in 1970 - Common Iguana *(Iguana iguana)* and Banded Basilisk *(Basiliscus vittatus)* among the four species bred in that year (Banks, 1984). From 1973-1985, an average of 11 reptile species per year was bred at the Zoo, with a peak of 15 species in 1979.

Notable successes during this period included:

The first Elongate Tortoise *(Indotestudo elongata)* hatches in 1974 - first in Australia.

Freshwater Crocodiles *(Crocodylus johnstoni)* hatch in 1975 - world first captive breeding (Dunn, 1977).

Thorny Devils *(Moloch horridus)* hatch (wild-mated female) in 1976 (Dunn, 1978).

Star Tortoise *(Geochelone elegans)* hatches in 1976 - first in Australia.

African Pythons *(Python sebae)* hatch in 1978 - first in Australia.

Saltwater Crocodiles *(Crocodylus porosus)* hatch in 1979 (Dunn, 1981).

Crested Basilisks *(Basiliscus plumifrons)* hatch in 1981 - first in Australia (Banks, 1983).

Arafuran File Snakes *(Acrochordus arafurae)* born in 1983 - world first captive breeding (Dunn *et al.*, 1987).

D'Albertis Pythons *(Liasis albertisii)* hatch in 1985 - third time in the world (Banks, 1985).

Important successes since 1985 include:

Twist-neck Turtles *(Platemys platycephala)* - one of only two non-native side-necks held in Australian zoos and not commonly bred in captivity.

Jackson's Chameleons *(Chamaeleo jacksoni)* - Melbourne Zoo has provided the display needs of other Australasian zoos for this species.

Frilled Lizard *(Chlamydosaurus kingii)* - Melbourne Zoo has regularly bred this species since 1994 and provided other zoos with founder stock.

Reticulated Gila Monster *(Heloderma s. suspectum)* - the two young hatched in 1998 marked the first successful captive breeding of this species in Australia.

Fijian Banded Iguana *(Brachylophus fasciatus)* - an important regional conservation pro-

gram for both species of Fijian Iguana, involving a number of Australasian zoos.

Striped Legless Lizard *(Delma impar)* - three young hatched in 1998. The first species of *Delma* captive-bred in Australia, and possibly the first pygopodid (Banks *et al.*, 1999).

Black-headed Python *(Aspidites melanocephalus)* - the first breeding in 1991 was an important breakthrough.

Philippine Sail-fin Lizard *(Hydrosaurus pustulatus)* - first breeding in Australia in 1996.

Eyelash Viper *(Bothriechis schlegelii)* - first captive breeding in Australia, in 1996.

Rhinoceros Viper *(Bitis nasicornis)* - first captive breeding in Australia, in 1997.

Since the current House was opened in October 1969, 82 species of reptiles and amphibians have been bred - 11 species of amphibians in two orders and five families, and 71 reptiles from three orders and 17 families.

A trend in recent years, expanded on later in this paper, is the control now applied to breeding many species, particularly non-native species in which the young produced cannot be satisfactorily placed. This includes species such as Corn Snakes *(Elaphe guttata)*, Taipans *(Oxyuranus scutellatus)* and a number of North American terrapins, e.g. *Chrysemys picta*. Other species, some of which are managed regionally within Australasian zoos, are only bred to meet specific display needs, e.g. Madagascan Day Geckos, *Phelsuma madagascariensis grandis*.

UPGRADING HOLDING FACILITIES

The current Reptile House presents animals in a range of naturalistic exhibits that utilise living plants and attempt to recreate the habitats of the species displayed. However, it was not purpose-built to house and display reptiles and amphibians, rather it was a conversion of a much older structure, which was originally erected in the 1930s as a large bird aviary. This approach, of course, is far from ideal, but is not uncommon when zoos are faced with limited budgets.

So, when the Reptile House was opened, significant problems soon became apparent. Foremost amongst these was an inability to appropriately control air temperatures in the off-limit holding areas. Due to the only barrier between these spaces and the external environment being a single thickness of corrugated iron or clear perspex, air temperatures were too low in winter and too high in summer. Apart from creating difficulties for the keepers in maintaining appropriate conditions for the animals, this system was wasteful of energy and not a good working environment for the staff. Among the issues relating to the latter point, the main heat source for the exhibits, an oil-fired burner that heated water in the pipes under the exhibits, was located in the centre of the main off-limit holding area (Fig. 3). This unit was not always reliable and periodically released amounts of smoke and fumes, adding to the frustrations and difficulties experienced by keepers at the time.

A second issue, which became apparent through the gradual change in working practices in zoos since the mid 1980s, was the need to upgrade the holding environments for the animals themselves. This reflected broader changes in zoos, particularly a shift towards holding more specimens of fewer species, because of more co-ordinated management of reptiles, and to more effectively meet the climatic requirements of those reptiles. Great strides had been taken in our understanding of, for example, the heating, lighting and moisture requirements of many species, and reptile keepers began more broadly to implement these advances within zoos.

When the building was opened in 1969, enclosures in the off-limit areas were arranged at one level on shelves and benches, including one heated table in the central area of the building. The enclosures them-

selves comprised a range of wooden boxes and glass aquaria of differing sizes. Apart from those on the heated table, heating for these enclosures was delivered by suspended infra-red heat lamps.

A three-pronged program to address these issues was commenced in 1987:

Conversion of the off-limit holding enclosures to tiered holding units.

Conversion of the heating source from oil to natural gas and relocation of the heating units outside the building.

Installation of insulation in the ceiling areas and compartmentalisation of the different off-limit areas.

1. Development of tiered holding units

The first five sets of tiered units were fixed to existing walls in the off-limit room on the building's south side. Each unit consisted of three levels of boxes varying from 762 x 610 x 914mm for the bottom row, to 457 x 457 x 457mm for the top row. Each unit comprised three enclosures on the bottom, three in the middle and four on the top row (10 enclosures in all). Each enclosure held two 25W blue light globes, for heating, and a 25W frosted globe, for additional light during servicing, with both mounted in a mesh box at the top of the back wall. Structural ply was used throughout, apart from glass fronts for viewing. All the enclosures had hinged fronts for easy access and the three bottom enclosures in each unit were separated by removable plywood slides, giving the capacity to provide an enclosure up to 1.8m long.

Nine sets of additional tiered units have since been built, with each new unit incorporating the latest available technology and knowledge from operation of the previous units. Sizes of individual enclosures have varied, depending on the range of species to be housed and available space. Better quality ply has been used for the later units and this has been varnished and the internal floor surfaces coated with fibreglass for hygiene and ease of cleaning. In all these subsequent units, the heating has comprised underfloor cables or heat tape, either embedded in concrete for the earlier units, or in shallow underfloor cavities in the latest units. Woven wire mesh (5mm gauge) has been used for the tops of these units and this feature, combined with spaces between the different levels, allows for use of heat lamps where necessary (usually 100 - 150W in specially designed covers), and low profile twin fluorescent light fittings (Fig. 4).

The heating and lighting for all the tiered units have been placed on thermostats and timers respectively, and the various controls have been wired to central panels for easy access and maintenance.

The same design principles have been applied to floor enclosures for aquatic reptiles, such as young crocodiles and freshwater turtles, ie. varnished marine ply boxes, with sloped fibreglassed floors and hinged wire mesh tops. Like the tiered units, these have also proven to be very flexible and, in addition to aquatic reptiles, have been used for groups of Shinglebacks (*Trachydosaurus rugosus*), Striped Legless Lizards (*D. impar*) and young land tortoises (*G. elegans* and *I. elongata*).

Design and development of new holding enclosures is a continual process as new techniques and ideas arise, and to accommodate new programs.

2. Conversion and relocation of primary heating units.

The old oil-fired burner was replaced with two new natural gas burners in 1988 when the Zoo undertook a major conversion to natural gas heating. These were located on a concrete slab outside the building, against its west wall. One unit is solely for heating water in the pools in the three large exhibits, ie. the two crocodile exhibits and the mixed freshwater turtle and lizard exhibit (referred to as "The Triple" because of its three sections). The second, larger unit heats the water that provides the heating for the rest of the exhibits and for keeper use, ie. taps and hoses.

3. Improving temperature control.

The replacement of the oil-fired burner provided the opportunity to properly address the inadequate temperature control in the centre of the House. Hence, an insulated false ceiling was installed, which sealed the large upper air-space in the building's original dome, and insulated plywood walls were erected around the outer edge of the central off-limit area. These included access doors into the ceiling cavities above the public gallery. Air conditioning was installed, with branches to other sections of the House. The combination of these features has resulted in a constant year-round background temperature of 21-24°C throughout this central area.

Other insulated walls were similarly installed to seal off other holding areas and these, plus the air conditioning, have greatly helped to ensure appropriate year-round temperatures in all areas of the House.

Another significant upgrading of holding facilities occurred in 1987. For some years prior, the Zoo had held reptiles seized by Department of Conservation & Natural Resources (DCNR) officers, pending the outcome of legal proceedings. The gradual increase in confiscations over 1985-87 placed increasing pressure on the Reptile Department's capacity to appropriately hold these animals and following discussions with the DCNR, a 68 sq.m extension was added to the Reptile House's south wall. The existing internal holding area was reconfigured and the outcome was a 36 sq.m reptile holding room (since used primarily for snakes), a 20 sq.m rodent holding and breeding room, and a 12 sq.m staff office.

REGIONAL MANAGEMENT

The world's zoos have had regional associations since the 1960s, most starting life as gatherings to exchange information and promote staff training. The current Australasian body, the Australasian Regional Association of Zoological Parks & Aquaria, Inc. (ARAZPA), has grown out of earlier groups, the foundation having been established in 1967 (Mumaw, 1992). The driving force behind the growth of these groups has been the desire to maximise the value of the animal collections in those zoos, particularly their role in wildlife conservation. This development has seen increasing links established with the conservation community, especially the IUCN's Species Survival Commission (SSC) and its various specialist groups (Seal, 1986). A prime example of these co-operative endeavours is the World Zoo Conservation Strategy, jointly collated by the World Zoo Organisation and the SSC's Conservation Breeding Specialist Group (IUDZG/CBSG (IUCN/SSC), 1993).

Within this region, these initiatives have moved forward under ARAZPA's Australasian Species Management Program, the ASMP (Baker & George, 1988), and the Association's Taxon Advisory Groups, or TAGs. The TAGs' primary roles are to co-ordinate the management of the respective species in Australasian zoos that are ARAZPA members, and provide direction and recommendations that maximise their display and conservation potential.

ARAZPA's Reptile and Amphibian TAGs were both established in April 1990, with Melbourne Zoo's Curator of Herpetofauna filling the position of Reptile TAG Convenor (Banks, 1993 & 1999a). This involvement has continued and expanded over subsequent years and Herp Section staff fill a number of TAG positions:

Convenor, Reptile TAG.

Species Co-ordinator for Aldabran and Galapagos Giant Tortoises.

Captive Program Co-ordinator for Philippine Crocodile.

TAG Contact for Frilled Lizard.

TAG Contact for Eastern Diamondback Rattlesnake.

In addition to these regional management roles, the Zoo's Herp Section holds and par-

ticipates in the management of specimens from 12 species that are co-ordinated by or through the two TAGs:

Philippine Crocodile, *C. mindorensis.*

Aldabran Giant Tortoise, *A. gigantea.*

Mary River Turtle, *Elusor macrurus.*

Striped Legless Lizard, *D. impar.*

Frilled Lizard, *C. kingii.*

Knob-tailed Geckos, *Nephrurus* spp.

Fijian Banded and Fijian Crested Iguanas, *B. fasciatus and B. vitiensis.*

Reticulated Gila Monster, *H. s. suspectum.*

Broad-headed Snake, *H. bungaroides.*

Eastern Diamondback Rattlesnake, *Crotalus adamanteus.*

Great Barred Frog, *M. fasciolatus.*

As previously mentioned, the growth of regional management has generally seen a reduction in the number of species held, with a concomitant increase in the number of specimens of those species which are of TAG interest. This development has also been reflected in the Zoo's Herp Section taking the responsibility for meeting the display needs of other zoos in the region, for a number of particular species, including Madagascan Day Geckos *(P. m. grandis)*, Jackson's Chameleons *(C. jacksoni)*, Eyelash Vipers *(Bothriechis schlegeli)* and various native frog species. These trends, and participation in conservation programs as outlined later, have driven the gradual changes in operating procedures, development of holding facilities and professional development of staff.

THE JUMP INTO FROGS

Despite the fact that most people like frogs and these are marvellous animals for talking about concepts such as development, communication and diversity of reproductive modes, frogs, and amphibians generally, are traditionally a sadly neglected group in zoo displays (Maruska, 1986; Peterson, 1996). Until recently, little serious attention was paid to captive breeding - only one species of newt and five frog species were bred in Australasian zoos in 1993 (ARAZPA, 1994).

A desire to address this failing, together with increasing awareness of global declines (Barinaga, 1990), were the twin stimuli that finally brought years of pushing for a dedicated frog display at Melbourne Zoo to fruition, in 1992. This also caused the Section to change its name from "Reptiles" to "Herpetofauna" to more accurately reflect its breadth of activities.

Designed completely in-house and with major funding support from the Confectionary Division of Cadbury Schweppes Pty. Ltd, the Zoo's "World of Frogs"complex was officially opened on 18 August 1993 (Banks, 1995). This comprised eight naturally landscaped exhibits of varying sizes, two off-limit research and breeding rooms, and an external wetland habitat. Up to 12 species of amphibians are displayed at any one time and a large glass window allows viewing into the breeding rooms. Each exhibit has its own lighting, heating, misting and biofiltration system.

The breeding rooms are fitted with tiered racks of holding tanks, of varying sizes, which have overhead lighting and misting systems. The tanks were designed to be very flexible in terms of depth of water they can hold and water:land ratio. The whole complex has its own aged water supply and a heating unit installed in the main line connected to hose outlets.

The external wetland comprises two ponds surrounded by appropriate local vegetation and there is an inground system of speakers that play calls of a range of local frog species.

"World of Frogs" has worked well in terms of providing a public display, although much effort is devoted to acclimatising frogs, naturally secretive creatures, to show themselves effectively. It has also proved to be a vital

resource for promoting breeding, with eight species having bred in the exhibits or breeding rooms since opening:

Blue & Gold Poison Arrow Frog, *Dendrobates tinctorius.*

Spotted Marsh Frog, *Limnodynastes tasmaniensis.*

Green Tree Frog, *Litoria caerulea.*

Eastern Dwarf Tree Frog, *L. fallax.*

Dainty Tree Frog, *L. gracilenta*

Giant Green Tree Frog, *L. infrafrenata* (Banks *et al.*, 1983; Banks & Leyden, 1990)

Southern Bell Frog, *L. raniformis.*

Fire-bellied Newt, *Cynops pyrrhogaster.*

Roseate Frog, *Geocrinia rosea* (fertile spawn).

Although "World of Frogs" has provided the main visitor focus for the Section's amphibian endeavours, the range of involvements has been much broader:

An *ex situ* conservation program for Romer's Tree Frog, *Philautus romeri*, in Hong Kong (Banks, 1996a).

Support for native frog recovery programs (see below).

Display and regular breeding of Blue & Gold Poison Arrow Frogs, *D. tinctorius,* including supply to other Australian zoos.

Regular participation in Frog Week activities.(Figure 5)

Regular breeding of the Great Barred Frog, *Mixophyes fasciolatus*, and discussions with NSW agencies to work with the vulnerable *M. balbus.*

Provision of young, captive-bred frogs to licensed private herpetologists.

Ongoing links with the Amphibian Research Centre (ARC) and other researchers studying the chytrid fungus.

Support for the ARC's "banana box frog program" (see Marantelli *et al.*, in press).

Support for field work (surveys, etc.).

Development and delivery of education programs, some of which were partly funded by Cadbury Schweppes Pty. Ltd., to school students and Zoo visitors.

Training of staff from other zoos in amphibian husbandry and breeding techniques, and enclosure design.

Support for special interest groups, e.g. CAE courses.

A MOVE INTO CONSERVATION

Melbourne Zoo Herp Section's direct involvement in conservation programs, particularly *in situ*, really began in 1990 and reflected stronger management support for such activities brought about by the arrival of a new Director. Since that time, most of the Zoo's animal sections have become involved in conservation programs, both based within the Zoo and off-site participation. For the Herp Section, apart from the species management programs already alluded to, direct conservation support has focused on six main species or groups.

Striped Legless Lizard, *Delma impar.*

The Striped Legless Lizard, *D. impar*, is listed as Vulnerable at both national and global levels, and as Endangered in Victoria (IUCN, 1996; Stanger *et al.*, 1998; NRE, 1999). It is restricted to native temperate grasslands across southern Victoria, where it is now found only in small scattered remnants, particularly in western Victoria, across Melbourne's western fringes and in the ACT. Its management is co-ordinated by a National Recovery Team and, in Victoria, by the Victorian Striped Legless Lizard Working Group (Banks, 1992). National and regional goals are specified in a National Recovery Plan (Smith & Robertson, in press).

Melbourne Zoo plays a key role in the Working Group, especially through provision of the Convenor and meeting venue, but it also acts as the location for receipt of all specimens rescued through salvage operations in Victo-

ria (Kutt *et al.*, 1995). Specimens at the Zoo are held, most pending future release in secure grassland, for biological and life history research, public display and as a resource for agreed genetic research. Zoo staff also support field work and salvage operations.

All of these goals have been met, including the first captive breeding of the species in 1998 (Banks *et al.*, 1999), and the lizard is also used by the Zoo as a key promotional vehicle for broader grassland conservation, including education programs and flora recovery.

Native Australian frogs.

The Action Plan for Australian Frogs lists 27 species as Vulnerable or Endangered and another 14 species that are ìinsufficiently known that may be of concern (Tyler, 1996). Through the development of public displays, such as the World of Frogs, and direct involvement in conservation programs, Melbourne Zoo's Herp Section has been endeavouring to support Action Plan goals since 1991:

Providing training for staff from other Australian and New Zealand zoos in frog husbandry and display, and enclosure design.

Breeding of Great Barred Frogs, *M. fasciolatus*, as an analogue for other threatened members of this genus, particularly *M. balbus* (Hawkes *et al.*, in press).

Captive management and rearing of *Geocrinia rosea* at the request of Western Australian agencies, in support of the threatened *G. alba* and *G. vitellina* (Birkett *et al.*, 1999).

Captive management of *Taudactylus acutirostris* at the request of the Queensland & Northern NSW Threatened Frog Recovery Team (Banks & McCracken, in press).

Romer's Tree Frog, *Philautus romeri*.

Romer's Tree Frog, *Philautus romeri*, is a small rhacophorid frog restricted to a handful of Hong Kong islands. The development of the new international airport threatened to destroy one third of the frog's breeding sites and requests were circulated for help with establishing off-shore colonies and locating potential re-release sites (Banks, 1996a). Melbourne Zoo subsequently assisted with the salvage of 30 frogs from the main island to be lost, Chek Lap Kok, and established a successful breeding program in the Reptile House. Over 800 captive-bred frogs were later returned to Hong Kong for release into new field sites identified by Hong Kong researchers. These releases, plus those of frogs and tadpoles bred at the University of Hong Kong, have all been successful and continue to be monitored by local scientists and volunteers (Dudgeon & Lau, 1999).

Philippine Crocodile, *Crocodylus mindorensis*.

The Philippine Crocodile, *Crocodylus mindorensis*, is the most threatened species of crocodile in the world, with probably no more than 100 adults remaining in the wild (Fig. 6)(Ross, 1998). The species is the second highest priority of the IUCN/SSC Crocodile Specialist Group (CSG), which called for a comprehensive National Recovery Plan, in 1991, as the most urgent conservation action (Messel et al., 1992).

Melbourne Zoo first became involved with the species in 1992, through links with the Zoo's Director and Silliman University on Negros Island. A tripartite Memorandum of Agreement was signed in January 1993, between the Zoo, Silliman University and the Philippine Department of Environment & Natural Resources. This provided the framework for directing funding and logistic support to Silliman University's breeding group, funding of a community awareness poster distributed throughout the Philippines and for importing crocodiles into Melbourne Zoo. Over the next few years, links were established with other centres in the Philippines, particularly the Crocodile Farming Institute on Palawan Island, and interested groups in the United States and elsewhere in Australia and New Zealand (Banks, 1996b).

The Zoo's efforts since 1996 have focused on liaising with all interested parties and maintaining pressure for developing the Recovery Plan, which was agreed at the 1997 CSG meeting. This is being written by Melbourne Zoo's Herp Curator, and, at the time of writing, the Plan's second draft has been agreed and all that remains is to finalise costing of agreed actions and who will undertake them. This will be discussed at a meeting in Manila in November 1999.

Philippine amphibians.

Like all faunal groups in the Philippines, the amphibians are under great threat from habitat loss and ongoing degradation. Despite the fact that less than 10% of the original lowland forest remains (Collins *et al.*, 1991), and species declines have been consistently reported over recent years (J.C. Gonzalez, pers. comm.), only two of the country's reported 81 species have been listed by the IUCN as under threat (IUCN, 1996). In an effort to address this and arrive at a better understanding of the status of Philippine amphibians, the Zoo's Herp Curator convened and chaired a meeting of Philippine herpetologists on Palawan in April 1999. This resulted in an additional 30 species being recommended to the IUCN and the Protected Areas & Wildlife Bureau (PAWB, Philippines) for inclusion on threatened fauna lists. These comprised two caecilians and 28 anurans (Banks, 1999b).

During discussions at the April assessment, the idea of an education program was raised as one way of helping to increase community awareness of amphibians in the Philippines. This has been followed up with a schools and community-based project being developed by Assist. Prof. Leticia Afuang at the University of the Philippines, Los Banos, on Luzon Island. The Zoo is helping to fund the project and providing editorial and technical advice.

South East Asian tortoises & freshwater turtles.

Tortoises and freshwater turtles have been used as food in south-east Asia for centuries, but a presentation at a 1997 herp meeting in Seattle shocked the herpetological community with the news that every species of these groups across southern Asia is facing extinction within the next 10-15 years (Kiester & Juvik, 1997). Driven by the burgeoning Chinese economy, tonnes of tortoises and turtles are being caught and moved through food markets each day! A 1995 TRAFFIC South-East Asia report documents trade in Elongate Tortoises, *Indotestudo elongata,* growing from being insignificant in 1988-90 to more than 720,000kg in 1993 (Jenkins, 1995). US herpetologists filmed 10,000 tortoises over just two days in two southern Chinese food markets in July 1997 (Collins, 1999). It is very easy to be totally overwhelmed by the magnitude of this issue.

The Australasian zoo community became aware of this problem at the Reptile TAG meeting in October 1997 and Melbourne's Herp Curator undertook to explore ways our zoos could assist. Since that meeting, strong contacts have been established with agencies, ngo's and turtle experts in Vietnam, Australia, the United States and Germany, including a visit to Vietnam in July 1998 to discuss some of the issues first-hand. Further, ARAZPA has endorsed a program of increasing the public display of relevant species in the region's zoos, complemented by appropriate interpretive material and request for support. All funds raised through this program are being directed to an *in situ* turtle conservation project in Cuc Phuong National Park in northern Vietnam and operated by Fauna & Flora International.

THE FUTURE

Melbourne Zoo Herp Section's operations and involvements have changed dramatically over the last 30 years and there is no reason to suggest that the next 30 years will see any decrease in this, as zoos themselves continue to evolve. Zoos have demonstrated that they have a range of roles in helping to conserve the natural biodiversity of this planet, which is surely the greatest challenge facing us all.

However, as with many organisations, zoos are undergoing a distinct phase of readjustment, brought about through the economic rationalist approaches of government and business. It is still a matter of debate as to just how far these can be applied to and in zoos. A second, and perhaps related issue, is the increase in regulations governing most aspects of zoo operations and especially as they relate to animal movements. This is straining the zoo-regulatory agency relationship and having negative impacts on conservation programs.

But this the reality of the world in which zoos, and Melbourne Zoo's Herp Section, operates. We have shown in the past the capacity to deal with issues that threaten to impede progress and I have no doubt that they we will continue to show the same level of resourcefulness and initiative into the next century.

ACKNOWLEDGEMENTS

Apart from his landscaping and artistic skills, Roy Dunn led the Section as Curator from 1969-1975. During this period he provided great support for the keepers on the Section and encouraged initiative and development of many of the breeding programs at that time.

Many keepers, both past and present, have contributed to the success of the Section over the past 30 years: Glyn Hoare, Greg Miles, Andrew Haffenden, Ditar Uka, Ken Hall, Peter Brown, Andrew Wegener, Jon Birkett, David Leyden, Sheila Rowe, Jim Thomas, Noel Harcourt, Josephine Downey, Matt Vincent, Megan Riescheck, Tim Hawkes, Gerry Marantelli, Merv Jenkins and Mike Swan.

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Figure 1. The Saltwater Crocodile exhibit in the Reptile House. (Photo, Chris Banks)

Figure 2. The Reptile House soon after opening, in April 1970. (Photo, Chris Banks)

Figure 3. Burner in the centre of the Reptile House in 1971. (Photo, Chris Banks)

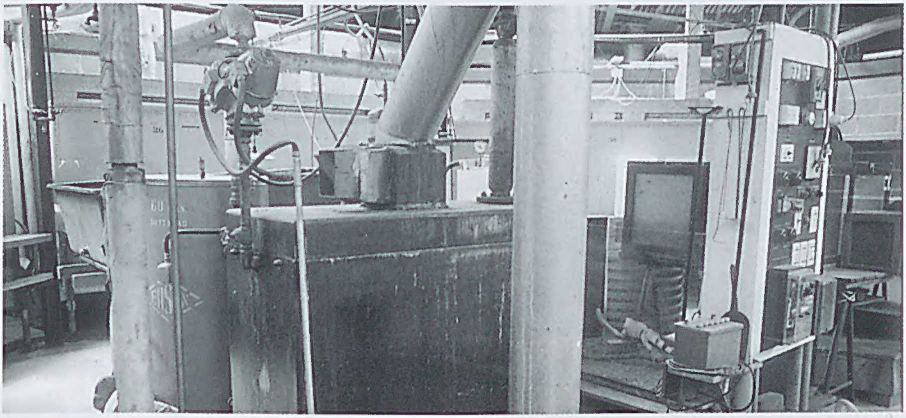

Figure 4. New off-limit lizard holding enclosures (1998). (Photo, Chris Banks)

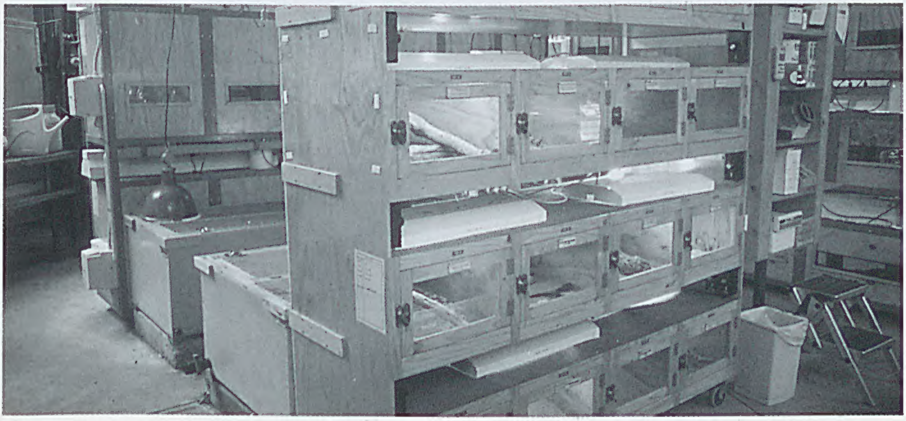

Figure 5. Frog Week festivities at Melbourne Zoo (1997). (Photo, Chris Banks)

Figure 6. Philippine Crocodile, *Crocodylus mindorensis* (Photo, Chris Banks)

NOTES TO CONTRIBUTORS

Herpetofauna publishes articles on any aspect of reptiles and amphibians. Articles are invited from interested authors particularly non-professional herpetologists and keepers. Priority is given to articles reporting field work, observations in the field and captive husbandry and breeding.

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Two copies of the article (including any illustrations) should be submitted. Typewrite or handwrite (neatly) your manuscript in double spacing with a 25mm free margin all round on A4 size paper. Number the pages. Number the illustrations as Figure 1 etc., Table 1 etc., or Map 1 etc., and include a caption with each one. Either underline or italicise scientific names. Use each scientific name in full the first time, (eg *Delma australis*), subsequently it can be shortened (*D. australis*). Include a common name for each species.

The metric system should be used for measurements.

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An early Australian Reptile Club field trip in 1949-1950

Photo: courtesy Roy Mackay. Thanks to Roy and David McPhee for identifications.

L to R: Hal Cogger, Ken Smith, Shirley Collins, Alex "Rusty" Holmes, Dennis Hosmer, Bill Hosmer, Mrs Scott-Sim, Barry Salkeld, ?, Roy Mackay, Alan Steel, ?, Neville Goddard, Kevin Budden. Two in front: Fred Fricke, Mrs Alex Holmes